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RADIOMETEOROGRAPHY AS APPLIED TO UNMANNED BALLOONS [1]

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INTRODUCTION

Widespread surface observations, taken at the same hour, have long been the basis of synoptic meteorology. Modern methods of weather analysis and forecasting require, in addition, synoptic data on the extent, motion, and characteristics of air masses within which and between which the weather takes place. If a complete synoptic picture is desired, vertical soundings up to 4 or 5 kilometers must be made twice daily, or oftener, at stations separated by not more than a few hundred miles; at each station the desired data include the direction and velocity of upper air winds, and the vertical distribution of pressure (*p*), temperature (*t*), and relative humidity (*f*). In some synoptic situations, and in many research problems, it may be desirable to extend observations far above the 5-kilometer level.[2]

For determining these upper air data, three methods of sounding are in wide present use:

(*a*) Free pilot-balloon observed by one or more theodolite stations on the ground; for determining the direction and velocity of upper air winds. Data are evaluated as they are observed.

(*b*) Airplane carrying a recording meteorograph which is returned to the surface station with *p*, *t*, and *f*-data taken during the sounding. Data are evaluated within an hour or two after they are observed.

(*c*) Free sounding-balloon with recording meteorograph, which may be reclaimed after the sounding is made. Data may be evaluated hours or days after they are observed, or may be lost entirely.

These present sounding methods have definite limitations. Complete pilot-balloon observations require clear weather and good visibility. Sounding balloons, while independent of weather, are slow and unreliable. In levels below 5 kilometers airplane sounding, being more rapid and far more certain, is usually preferable to balloon sounding. But the airplane cannot operate safely in unfavorable weather, when soundings are most urgently needed; and above 5 kilometers, which is a practical ceiling for ordinary airplanes, free balloons are necessarily used.

Within recent years the application of radio technique to meteorological balloons has developed new sounding methods which may largely transcend the limitations indicated above. In fair weather or foul, radio transmission can convey instantly to the surface observing station either the balloon's position, or the air characteristics being encountered at any moment during its ascent, or both. In practice either the simple pilot-balloon or the meteorograph-equipped sounding balloon is combined with a small radio transmitter light enough to be conveniently lifted by the balloon. In the case of a radio pilot-balloon, the radio transmitter is excited either intermittently or continuously during the ascent, while bearings are taken on it by one or more directional radio receivers on the ground. In the case of the radio sounding-balloon, the meteorograph continuously indicating *p*, *t*, and *f* as the balloon ascends is caused so to vary some element of the radio transmission, or to interrupt the transmission in such a way, that nearly simultaneous records of *p*, *t*, and *f* during the ascent are conveyed to a receiver on the ground. A radio sounding-balloon can also serve simultaneously as a radio pilot-balloon.

OBJECTS OF PAPER

The objects of this paper are:

(*a*) To review briefly the historical development of radio pilot balloons and radio sounding balloons.

(*b*) To inquire into possibilities of improving the present state of balloon radiometeorography.

(*c*) To evaluate radio balloons in terms of their probable future usefulness.

HISTORICAL [3]

Standard meteorograph.—The standard three-element meteorograph, recording *p*, *t*, and *f* as simultaneous ordinates against time as abcissa, was available in completed form before research on the radiometeorograph began. Its basic elements are shown in figure 1. *C* is a cylinder revolved at a suitable rate by clockwork; *p* is the pressure arm, activated through suitable levers by either a syphon vacuum chamber or a Bourdon vacuum tube; *t* is the temperature arm, activated by a bimetallic strip; *f* is the relative humidity arm, activated by a multiple strand of human hairs. One or more elements of the standard meteorograph have been included in every radio-sounding balloon.

Radio design.—Balloon radiometeorography became fully practicable when small, efficient, short-wave transmitters were developed in the radio field. Thereafter, radio design by the various investigators in telemeteorography proceeded along similar and conventional lines. The most efficient generator of stable electric oscillations, and hence of receivable radio waves, is a single triode electronic tube connected to suitable external inductance and capacitance, with or without electro-mechanical (crystal) stabilization of frequency.

[1] Presented as a thesis at California Institute of Technology for the degree of Master of Science.
[2] Important military applications of radiometeorography are the determination ofballistic wind and ballistic density for artillery use.
[3] The writer's thanks are due C. F. Talman, Librarian of the U.S. Weather Bureau,for several of the references included.

Figure 2 shows the Hartley self-stabilized oscillator circuit, which has been used by many radiometeorograph investigators. (As will be pointed out later in this paper, better self-stabilized oscillator circuits are available, and should be investigated.) In figure 2, T is the electronic tube, L_1 and L_3 are inductances, C_1, C_2, and C_3 are capacitances; R is a resistance. Frequency and output are

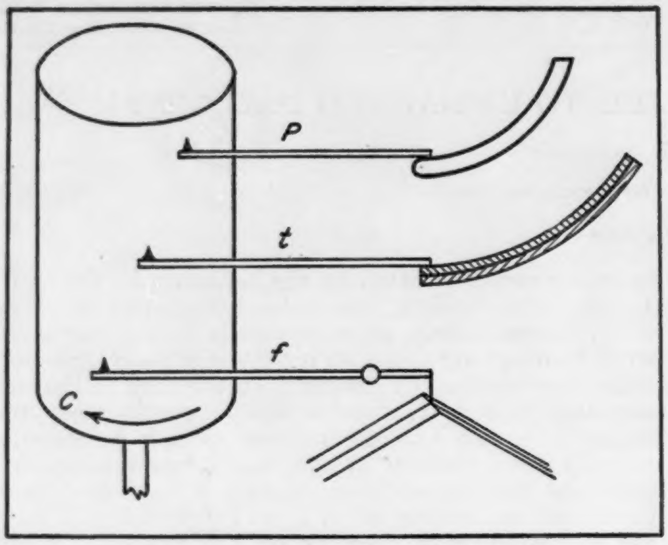

FIGURE 1.—Standard meteorograph principle.

determined by C_1 (usually variable) and L_1. At low-plate voltages the R-C_3 combination may be omitted, the grid being operated at zero bias. All these circuit parts, comprising the actual transmitter, need weigh no more than 100 grams. The battery A, delivering between 0.1 and 0.3 ampere of current at 1 to 4.5 volts, weighs 50 to 200

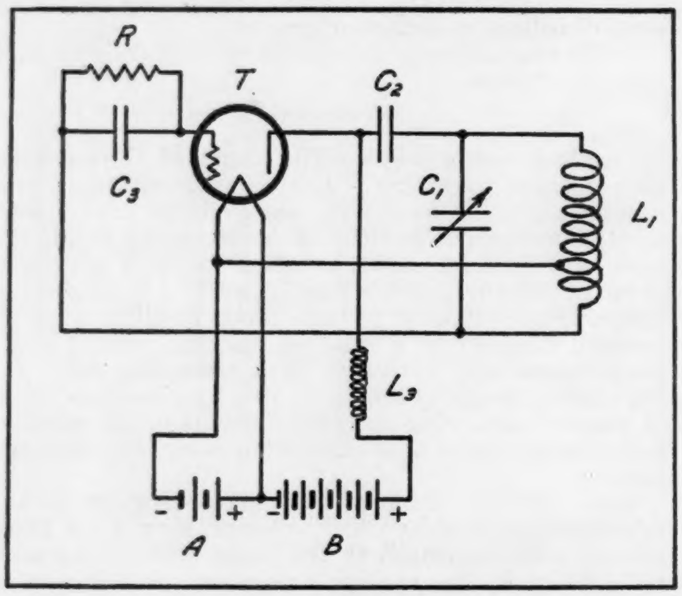

FIGURE 2.—Self-stabilized oscillator circuit.

grams. The battery B, delivering a few milliamperes of current at 25 to 150 volts, weighs 100 to 1,000 grams. It is possible to replace the relatively heavy B battery required for higher plate voltages with a small buzzer-transformer, weighing less than 200 grams and driven by the A battery.

Figure 3 shows a suitable crystal-stabilized oscillator circuit, which has been used by some investigators on account of its superior frequency stability. Here the frequency is determined by the dimensions of the crystal X, and the output is determined by C_1 and L_1. Both L_3 and R may be used, or either alone. Batteries (not shown) are the same as in figure 2.

In order that appreciable amounts of radio-frequency energy may be radiated toward the receiver, the oscillator is suitably coupled to an antenna, which may be a single wire one-half wave-length long, with the entire transmitter suspended at its center. Antenna weight is less than 100 grams. Wave lengths so far used for radio sounding-balloons have ranged from 20 to 150 meters (15,000 to 2,000 kilocycles).

Beginning of telemeteorography.—Outstanding among the pioneers of telemeteorography was Olland (**A**), a Dutch instrument maker. About 1875 he invented a system for the electrical indication of one or more meteorological elements. The same principle is used today in modern radiometeorography (fig. 7). It embodies: (*a*) indicating arms, arranged on a common center, which move radially in response to meteorological changes, one indicating arm serving for each meteorological element; (*b*) fixed reference marks on a circle, between (or in some definite relation to) the indicating arms and their limits

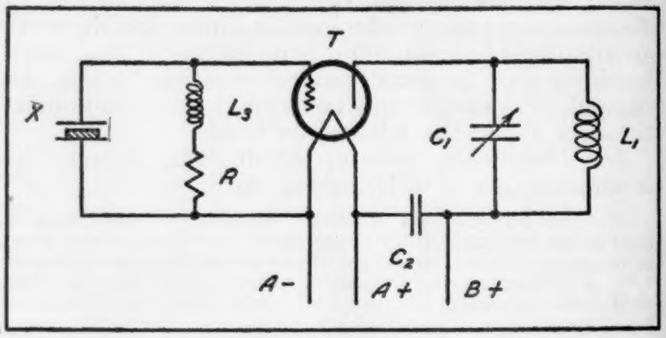

FIGURE 3.—Crystal-stabilized oscillator circuit.

of movement; (*c*) a revolving contact arm, pivoted concentrically with the indicating arms, and making electrical contact with them and with the fixed reference marks in turn during its clockwork-driven progress around the circle.

Contemporaneous with Olland was Van Rysselberghe of Belgium, who developed telemeteorographic apparatus which was widely used.

About 1917 Herath and Robitzsch applied the older methods of telemeteorography to aerology. Their apparatus gave temperature or pressure indication from a kite by means of alternating current in the kite wire.

Radio pilot-balloon.—About 1921 Herath in Germany began experimentation with radio pilot-balloons. The balloon carried a battery-driven buzzer oscillation circuit which was in effect a miniature spark transmitter. This oscillation system has many disadvantages, chief among which is that the radiated energy, being spread over a broad spectrum, gives only a faint signal in the narrow frequency band covered by the receiver. Herath's apparatus was not very satisfactory in either range or accuracy.

About 1923 W. R. Blair (**6**) (Signal Corps, United States Army) began work with radio pilot-balloons. The initial development included a small buzzer trans-

mitter, weighing less than a pound, which could be tracked for 20 minutes to a height of about 3.5 kilometers.

About 1927 Idrac and Bureau (1) of France sent up an unmanned balloon equipped with a small continuous-wave (electron tube) transmitter. The total apparatus weight was 2.7 kilograms. Signals on 42 meters were heard during the entire sounding, which extended up into the stratosphere.

About 1928 the Signal Corps, United States Army (6) developed an electron-tube transmitter for pilot-balloons, which weighed less than 0.5 kilogram complete with batteries and antenna. The relatively heavy B battery was eliminated in favor of a buzzer-transformer which weighed about 200 grams. Many tests were carried out on wave lengths near 125 meters, including actual tracking of the balloon by means of specially developed direction-finding receivers on the ground, the radio bearings being checked by theodolite observations. The balloon could easily be followed, with useful azimuth readings, to more than 15 kilometers distance from the ground stations. Within 8 kilometers distance, the radio bearings were accurate to ± 0.5 degree.

Radio sounding-balloons.—About 1924 Blair (6), in the course of researches mentioned above, did some experimental work with temperature indication from a radio pilot-balloon.

Between the years 1925 and 1933 research in radiometeorography was carried forward chiefly by the investigations of R. Bureau (3) in France, P. Duckert (4), (9), (11), in Germany, and P. Moltchanoff (2), (5), (7), in Russia and Germany, who worked contemporaneously on the problem. The first actual soundings were made about 1929.

The principle of Bureau's apparatus is shown in figure 4. *C–I* is a cylinder formed partly of conducting material (*C*) and partly of insulating material (*I*), and rotated by

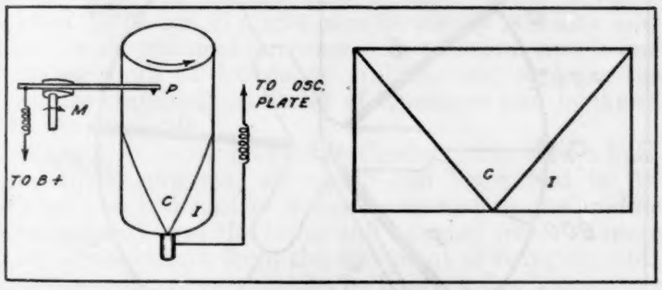

FIGURE 4.—Bureau radiometeorograph principle.

clockwork. *M* is an eccentric cam, rotated at a much faster rate than *C–I*. *A* is an arm indicating temperature, pressure, etc., by the vertical position of its contact point *P*. When *P* is over the conducting portion of the cylinder, dots are transmitted as the cam *M* makes and breaks contact. When the point *P* is over the insulating portion of the cylinder, no dots are transmitted. The number of dots in a series therefore indicates the vertical position of *P*, and hence the temperature, pressure, etc. The system is not limited to the indication of one meteorological element; temperature, pressure, etc., arms can be connected into the circuit in turn by switching cams. For temperature soundings this device gave an accuracy of $\pm 0.7°$ between $+20°$ and $-60°$ C.

Figure 5 shows the principle used by Duckert for continuous indication of temperature. The bimetallic strip *T*, by means of the lever connection *A*, varies the capacity of the condenser *C* in the oscillating circuit, which in turn varies the emitted frequency. A similar principle was used by Blair in the United States.

For pressure indication Duckert used the simple sliding-contactor scheme shown in figure 6. The pressure tube *T*, acting through suitable levers, causes the contact arm *A* to slide along the segment *S*, touching the contacts *c* in turn. Dashes are therefore transmitted, corresponding to definite steps of pressure change perhaps 50 to 100 mb apart.

Duckert used wave lengths between 30 and 60 meters. The accuracy of his apparatus was $\pm 0.2°$ for temperature and ± 1.5 millimeters for pressure. In addition to the more practicable temperature-varied condenser system, he devised a system of continuous-temperature indication based on the fact that an oscillating crystal changes its

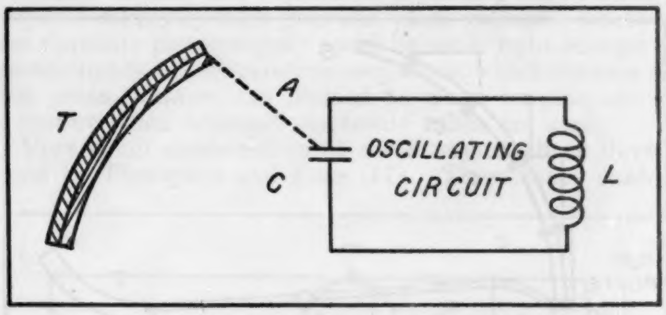

FIGURE 5.—Duckert temperature-indicating principle.

frequency with temperature. In addition, he developed light-weight transmitters and improved methods of thermal insulation, such as enclosing the entire transmitter in a glass vacuum bulb. Duckert's latest radiometeorograph is manufactured commercially by the Telefunken Co. in Germany.

Moltchanoff proposed, in his 1928 paper, a telemeteorographic principle similar to that of Olland. His first working model, however, used for pressure indication the system shown in figure 6; and for temperature indication an extension of this system involving multiple cams which transmitted 1, 2, 3, and 4 dots in turn.

In a later meteorograph, now manufactured commercially by Askaniawerke in Germany, Moltchanoff developed the principle of Olland into the form shown in figure 7. This device keys the transmitter in such a way that the time intervals between dots and dashes, which can be automatically recorded, give indication of pressure, temperature, and relative humidity in turn. In figure 7, *p*, *t*, and *f* are concentrically pivoted and move radially, within the limits of their respective scales, in response to pressure, temperature, and humidity. Separating the *p*, *t*, and *f* scales are the fixed contacts c_1 and c_2 and the synchronizing contact *S*. *p*, *t*, *f*, c_1, c_2, and *S* are all electrically connected to the oscillator plate. Concentrically pivoted with *p*, *t*, and *f*, but insulated from them, is the contact arm *C*, rotated by clockwork at about two revolutions per minute and electrically connected to *B+*. In the course of *C*'s revolution, the platinum wire *W* contacts *p*, c_2, *f*, *S*, *t*, and c_1 in turn, transmitting a dot for each contact except *S*, which results in a dash. The time interval between a fixed contact such as c_1 and a movable contact such as *p* indicates the pressure, etc., being encountered by the device at the time. The entire radiometeorograph, which operates on wave lengths between 25 and 100 meters, weighs 1.4 kilograms. Reception and evaluation are best accomplished by a standard facsimile receiver, whose recording cylinder is synchronized with the contact arm *C*. Curves having time (alti-

tude) as abcissa and p, t, and f as ordinates are thus directly recorded as the sounding is made.

About 1932 Väisälä (12), in the course of radiometeorograph research, devised some notably light batteries of lead-acid type. His 4-volt, 15-ampere-minute A battery weighed 38 grams; and his 72-volt, 1-ampere-minute B battery weighed 72 grams.

For additional details of radiometeorograph development, the reader is referred to the historical paper by Duckert (8).

POSSIBILITIES OF IMPROVEMENT IN RADIOMETEOROGRAPHY

Direction of future development.—Present models of the radiometeorograph give satisfactory performance. Future development will probably be directed chiefly toward lightness, simplicity and low cost. For radiometeorographs operating up to 6 kilometers altitude, the following weights are desirable upper limits: Batteries and other power supply, 150 grams; transmitter (including thermal insulation and antenna), 100 grams; meteorograph and clockwork, 150 grams; balloon, 150 grams; total weight, 550 grams. For radiometeorographs operating up to 30 kilometers: Batteries, etc., 250 grams; transmitter, etc., 150 grams; meteorograph, etc., 150 grams; balloon, 250 grams; total weight 800 grams. Simplicity is to be gained by standardizing the best and simplest telemeteorograph system available, and by using the simplest radio transmitter circuit that will give adequate performance (output and frequency stability). Low cost can be obtained partly through this simplification, and partly through manufacture of standardized units in fairly large quantities. A desirable upper limit of cost is $25 (exceeded at present) which would enable the radiometeorograph to compete economically with the sounding airplane, even assuming the loss of the balloon.

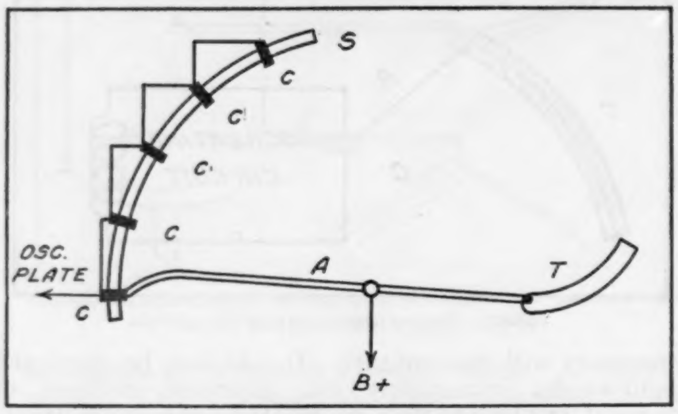

FIGURE 6.—Duckert-Moltchanoff pressure-indicating principle.

Possible methods of p, t, etc. indication.—The possible ways in which meteorological changes can be translated into intelligible radio indications are four in number, as follows:

(*a*) By varying the intensity of the transmitted signal. Unsatisfactory, as the signal intensity at the receiver is also subject to undesired and uncontrolled variation.

(*b*) By varying carrier frequency (bimetallic strip forming or mechanically coupled to one plate of a condenser in the oscillating circuit, etc.). This system is used and advocated by Duckert, who stresses the advantage of continuous temperature indication. At fairly uniform rates of ascent, however, a smooth temperature curve can easily be plotted from points intermittently recorded. Moreover, where the carrier frequency itself indicates the meteorological element, inordinate precautions are necessary to avoid slight undesired frequency changes that would otherwise be negligible.

(*c*) By modulating the carrier frequency and varying the modulation frequency. Believed to be too uncertain, and too cumbersome from the viewpoint of weight and cost.

(*d*) By interrupting, or keying, a signal of reasonably constant amplitude and frequency, which may be either continuous wave- or tone-modulated. This system, as exemplified in the Bureau and Moltchanoff devices, is believed by the present writer, in view of the known characteristics of radio apparatus and radio transmission, to be most worthy of future development.

Improvement of indicating meteorographs.—In the opinion of the present writer, the telemeteorograph as invented in 1875 by Olland and adapted to radio sounding-balloons more recently by Moltchanoff, has not been surpassed in simplicity and completeness of working principle by any later development. It is light, relatively simple, and permits the direct recording of practically continuous p, t, and f curves against time or altitude. It is possible that some better telemeteorographic principle will be invented. But as the Olland principle is now amply satisfactory, it would appear more profitable to concentrate immediate research in radiometeorography on other subfields such as radio technic.

Radio improvements, general.—In this field much progress in the direction of lightness, simplicity, and low cost remains to be made. Conventional radio apparatus, as so far applied to radiometeorography, can be considerably improved. It appears to the present writer that the most favorable short waves (5 to 20 meters) have not been used. Moreover, the field of ultra-short waves (1 to 5 meters) and micro-waves (<1 meter) has not even been touched.

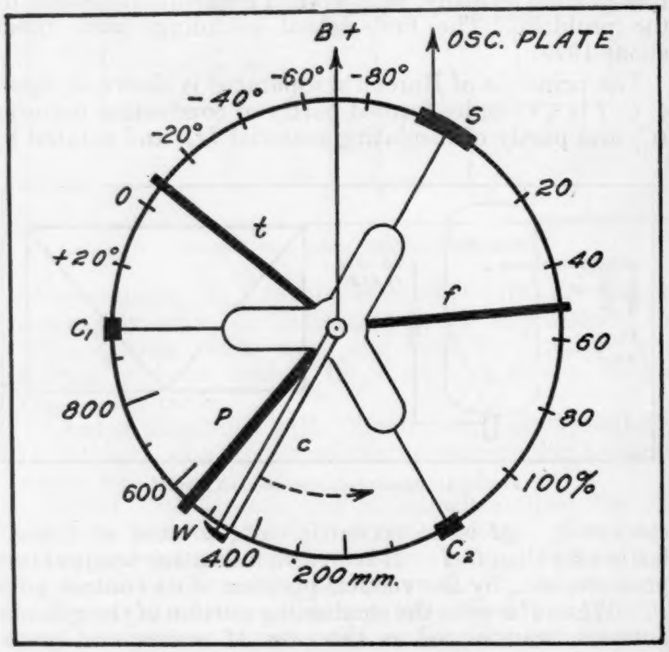

FIGURE 7.—Olland telemeteorograph principle.

Power supply improvements.—Small lead-acid batteries of A and B types, as developed by Väisälä, are probably near the ultimate in light-weight design. Dry-cell batteries are more convenient to use, and would probably give satisfactory electrical capacity in relation to weight. Dry cells which have been stored for any length of time, however, are in uncertain condition, whereas lead-acid batteries can be filled and charged before use. Also, the constant-voltage characteristic of the lead-acid A battery is particularly suitable for electronic filament operation. As a substitute for the B battery, the buzzer-transformer

is worthy of careful consideration, particularly as it produces a relatively broad, tone-modulated signal which is easily received. Its performance, however, depends on the adjustment of its vibrating contact, which may change considerably in response to large temperature changes. Enclosure of the contact or the entire device in a glass vacuum bulb, which might also enclose the entire transmitter, would be worth considering.

Improvements in ordinary short-wave technique. ($\lambda > 5$ meters).—In contrast to the 20 to 150 meters spectrum so far used in radiometeorography, wave lengths below 15 meters have three advantages: (*a*) Effective transmitting antennas are smaller and lighter; (*b*) oscillator circuit arrangements are smaller, lighter, and often simpler; (*c*) the 5 to 15 meters region is removed from the high-power interference which blankets the long-range wave lengths above 15 meters.

Receivers.—Receivers for 5 to 15 meters are of conventional design, somewhat refined, and can easily be combined with recording devices. Moreover, it is possible to use loop aerials for tracking radio pilot-balloons at wave lengths down to 5 meters. Whether these shorter waves would suffer greater directional vagaries than longer waves, would have to be determined by experiment.

Transmitters.—Before optimum transmitter design in radiometeorography is reached, one important question must be answered: Is crystal frequency stabilization necessary, or desirable? The crystal does insure better frequency stability. But it also entails slightly greater weight and complexity, and considerably greater cost. Using tone-modulated waves, as produced by buzzer-transformer plate supply, self-stabilized circuits will certainly suffice, and with correct circuit design and adequate thermal insulation, they may suffice for continuous waves. The tuned plate-tuned grid circuit, or the simpler tuned-plate variation of it shown in figure 8, is inherently more stable than the ordinary Hartley circuits so far used in radiometeorography. With suitable thermal insulation, it might give frequency stability adequate for all practical purposes. In addition, simple and cheap methods of frequency stabilization, such as the resistance-stabilized oscillator of Kusunose and Ishikawa (**13**), are available.

Antennas.—So far most investigators have used a half-wave dipole antenna, the upper end being tied to the balloon, the transmitter being connected in the middle (current feed), and the lower end hanging free. A more stable arrangement, from the viewpoint of swinging, etc., in shifting air currents, might be hanging the transmitter (perhaps equipped with damping vanes of light pasteboard) at the lower end of the half-wave dipole, which in this case would be voltage-fed.

Use of ultra-short waves and micro-waves. ($\lambda < 5$ meters).—This entire field, entirely unexplored so far as meteorography is concerned, shows considerable promise in certain directions. According to Beverage, Peterson, and Hansell (**14**) wave propagation in this region is in general optical with considerable diffraction at the higher wave lengths, becoming strictly optical at about λ 1 meter. In balloon radiometeorography this optical characteristic is no disadvantage, as there will always be a direct air path between a normally rising balloon and a properly located ground station.

Receivers.—Receivers for this wave-length region are highly specialized, being mostly of superregenerative and superheterodyne types. They can easily be adapted to radiometeorographic indication and recording. For radio tracking of pilot-balloons, several possibilities appear. The half-wave dipole, giving a minimum signal when the transmitter is on a line with it, is compact and easily movable at wave lengths below 10 meters. Antenna array or "beam" systems, as developed by Yagi (**15**) and others, become reasonably small and wieldy at about λ1 to 2 meters, and have distinct direction-finding possibilities. Finally, in the micro-wave region below λ0.2 meter, solid reflectors (and even lenses) of optical type are feasible, offering some interesting possibilities in three-dimensional direction finding.

Transmitters.—In the ultra-short wave and micro-wave regions several types of transmitters, as summarized elsewhere by the present writer (**16**), are available, though probably not all suited to radiometeorography. The magnetron oscillator, which reaches very short wave lengths, is definitely too heavy. The Barkhausen-Kurz oscillator circuit, also capable of producing micro-waves, requires relatively high grid and plate voltages; whether the requisite power supply could be made light enough is questionable. Regenerative oscillators, which operate at low plate voltage, are limited to wave lengths above 2 meters when ordinary electronic tubes are used.

Very small electronic tubes have recently been developed by Thompson and Rose (**17**). These tubes enable

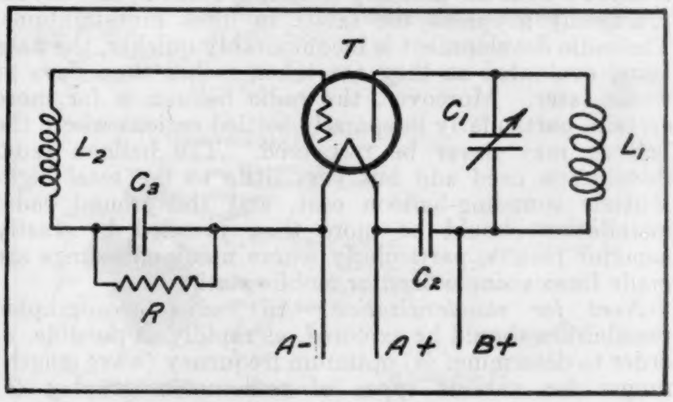

FIGURE 8.—Tuned-plate oscillator circuit.

the regenerative oscillator to reach wave lengths less than 1 meter and may permit other circuit developments of importance in radiometeorography.

PROBABLE FUTURE USEFULNESS OF RADIO BALLOONS

Classification of types.—Radio balloons will naturally be grouped into two types, pilot-balloons and sounding-balloons, as they are used (*a*) to determine upper-air motion or (*b*) to determine upper-air characteristics. In addition, the writer envisions pilot-balloons and sounding-balloons of two general classes: (1) low-altitude (up to 6 kilometers) and (2) high altitude (up to 30 kilometers). These two classes may be exactly similar in principle, but must differ in certain details such as power of radio equipment, thermal insulation, scale of meteorographic instruments, etc.

Radio pilot-balloons.—Any radio sounding-balloon can, of course, serve simultaneously as an ordinary pilot-balloon in clear weather; or as a radio pilot-balloon in poor visibility, provided that adequate direction-finding receivers are available on the ground. It is possible that, due to wave-transmission characteristics, radio pilot-balloons will develop along separate lines, using a frequency spectrum widely different from that suited to radio sounding. It is also possible, however, that the same frequency range may serve for both sounding and tracking; in which case one might envision a combined radiometeorographic instrument of either low-altitude or

high-altitude type, which could be used complete for sounding with or without tracking, or used for tracking only without its detachable meteorographic unit. In any case, it is clear that for upper-wind determination in poor visibility the radio pilot-balloon has no practical competitors, and its use is clearly indicated under these conditions.

Radio sounding-balloons.—Subdivided into probable low-altitude and high-altitude classes.

Low-altitude class (up to 6 kilometers).—This class competes with airplane sounding, which is already satisfactory, getting the data back with certainty for evaluation 1 or 2 hours after they are taken. In weather dangerous to flying, which is often the form of weather most deserving of investigation by soundings, the radio balloon is markedly superior to the airplane, and its use is indicated even at present cost levels. Even in fair weather, the radio balloon gets the data back more quickly than the airplane, and may, with standardization and mass production, prove superior from a cost viewpoint, particularly in settled regions where the percentage of returned balloons is reasonably high.

High-altitude class (up to 30 kilometers).—This class competes with the ordinary sounding balloon, and should practically supplant the latter in most investigations. The radio development is incomparably quicker, the data being evaluated as they are taken rather than days or weeks later. Moreover, the radio balloon is far more certain, particularly in sparsely settled regions where the balloon may never be recovered. The balloon radio installation need add but very little to the total high-altitude sounding-balloon cost, and the ground radio installation should be more than justified by vastly superior results, particularly where many soundings are made from a single fixed or mobile station.

Need for standardization.—All radiometeorographic possibilities should be explored, as rapidly as possible, in order to determine: (*a*) optimum frequency (wave length) ranges for various types of radiometeorographs; (*b*) optimum apparatus design for most efficient use of these frequencies. Considering past and present trends in the development of both meteorographic and radio technique, it seems probable that such optimum design, once reached in the present state of the art, will remain reasonably efficient for some years. This will permit the standardization and large-scale production which alone can make the full benefits of radiometeorography available to modern meteorology.

REFERENCES TO LITERATURE CITED

A. M. Snellen—"Le télémétéorograph d'Olland"—Archives Neerlandaises, V 14, 1879;

B. M. Snellen—Telemeteorographie—Meteorologische Zeitschrift, V 13, 1896, p. 365.

1. P. Idrac and R. Bureau—"Expériences sur la propagation des ondes radiotélégraphiques en altitude"—Comptes Rendues, V 184, March 1927, p. 691.

2. P. Moltchanoff—"Zur technik der erforschung der atmosphäre"—Beiträge zur Physik der freien Atmosphäre, V 14, n 1–2, 1928, p. 45.

3. R. Bureau—"Sondages de pression et de temperature par radiotélégraphie"—Compt. Rend., V 188, June 1929, P. 1565.

4. P. Duckert—1er Rapport de la Comm. Int. de l'Année Polaire 1932–33, Leydn 1930.

5. P. Moltchanoff—"Erforschung der höheren atmosphärenschichten mit hilfe eines radiometeorographen"—Leningrad 1930.

6. W. R. Blair and H. M. Lewis—"Radio tracking of meteorological balloons"—Proceedings of the Institute of Radio Engineers, V 19, n 9, 1931, p. 1531.

7. P. Moltchanoff—"Die methode der radiosonde und ein versuch ihrer anwendung bei der erforschung der höheren atmosphärenschichten in den polarregionen"—Gerlands Beiträge zur Geophysik, V 34, n 3, 1931, p. 36.

8. P. Duckert—"Die entwicklung der telemeteorographie und ihrer instrumentarien"—Beit. z. Phys. d. fr. Atm., V 18, n 1, 1931, p. 68.

9. P. Duckert and B. Thieme—"Neue radiometeorographische methoden"—Beit. z. Phys. d. fr. Atm., V 18, n 1, 1931, p. 50.

10. J. F. H.—"The modern radio-meteorograph"—Nature, V 130, December 31, 1932, p. 1006.

11. P. Duckert—"Das radiosondenmodell telefunken und seine anwendung"—Beit. z. Phys. d. fr. Atm., V 20, n 4, 1933, p. 303.

12. V. Väisälä—"Bestrebungen und vorschläge zur entwicklung der radiometeorographischen methoden"—Societas Scientiarum Fennica (Helsingfors), Commentationes Physico-Mathematicae, V 6, n 2, 1932.

13. Y. Kusunose and S. Ishikawa—"Frequency stabilization of radio transmitters"—Proc. I. R. E., V 20, n 2, 1932, p. 310.

14. H. H. Beverage, H. O. Peterson and C. W. Hansell—"Application of frequencies above 30,000 kilocycles to communications problems"—Proc. I. R. E., V 19, n 8, 1931, p. 1313.

15. H. Yagi—"Beam transmission of ultra-short waves"—Proc. I. R. E., v 16, n 6, 1928, p. 715.

16. W. H. Wenstrom—"Historical review of ultra-short-wave progress"—Proc. I. R. E., V 20, n 1, 1932, p. 95.

17. B. J. Thompson and G. M. Rose, Jr.—"Vacuum tubes of small dimensions for use at extremely high frequencies"—Proc. I. R. E., V 21, n 12, 1933, p. 1707.

THE WEATHER OF THE GREAT TILLAMOOK, OREG., FIRE OF AUGUST 1933

By CHARLES I. DAGUE

[Fire-Weather Service, Weather Bureau, Portland, Oreg.]

(Graphic presentation prepared by William G. Morris, junior forester, Pacific Northwest Forest Experiment Station)

One of the largest and most devastating forest fires ever known in Oregon, now referred to as the "Great Tillamook Fire", occurred in the northwestern part of the State the latter part of August 1933, starting on the 14th and reaching its climax on the 26th. According to Lynn F. Cronemiller, Oregon State forester, the Tillamook fire will go down in history as one of the greatest in the United States from the standpoint of timber loss and it undoubtedly was the greatest forest fire ever fought in the Northwest. Low relative humidities, fresh to strong easterly winds, and high temperatures were responsible for this huge fire which started from a tiny spark caused by the friction of one log being dragged across another on an active logging operation at a time when weather conditions were just right for a blow-up. Although the logging crew on the operation where the fire started made immediate efforts to extinguish the flames, the fire nevertheless was soon out of control, crowned through nearby timber and raced up the hillside. In fact, the crew was getting ready to quit for the day on account of the bad fire-weather conditions when the fire broke out; a number of the crew were already on their way to camp. Estimates by the Pacific Northwest Forest Experiment Station place the burned over area at 261,640 acres, of which 185,038 acres represent virgin timber lands, 54,955 acres second growth, and the remainder old burns and cut-over lands. The experiment station estimates that 10,968,819,000 board feet of standing timber was burned or damaged.

Another large fire, the Wolf Creek fire, started about 4 p.m. on August 24 in 300 acres of 3-year slashings about 10 miles north of where the Tillamook fire started on August 14. By midnight of the 25th, this fire had run a distance of 11 miles from where it started. Change of wind direction on the afternoon of the 26th from easterly to westerly caused the fire to reverse its direction of travel, burning back over itself and burning up a large logging camp that had previously been saved. The Wolf Creek fire burned over an area of 43,115 acres, of which 26,000 acres represent virgin timber lands of the finest type, 7,000 acres of timber lands with trees about 20 inches in diameter, and the rest old burns and cut-over lands. The Pacific Northwest Forest Experiment Station estimates the fire killed nearly 1,500,000,000 board feet of timber. This was a large forest fire, but in great measure was lost sight of at the time by the public in general because of the major proportions assumed by the Tillamook fire.

The low relative humidities, fresh to strong easterly winds and high temperatures result from the slow progressive eastward movement of high-pressure areas over the northern plateau and Rocky Mountain regions. As these high-pressure areas move east and southeastward, the normally low-pressure trough over the interior of California of the summer months usually builds northward over the western portions of Oregon and Washington into British Columbia and Alaska, also off the adjacent coasts, bringing about a steeper barometric gradient to increase the strength of these easterly winds at such times over the Pacific Northwest. These are the pressure conditions that prevailed during the bad fire-weather periods of August 10 to 16, and August 21 to 26. Pressure gradients were somewhat weaker, however, during the first period than during the second when the worst fire-weather conditions prevailed. The center of high pressure also moved in farther south over Western Canada during the second period than during the first, particularly on August 25 and 26, when the worst fire-weather conditions prevailed and the fire made its largest run and did its greatest damage.

Since this article is dealing with weather and its relation to the great Tillamook fire, discussion is being confined largely to the weather which prevailed at the time over northwestern Oregon, particularly over the northern Coast Range where the fire occurred. Figure 1 is a map of northwestern Oregon showing the location of the fire, where it started, the approximate area burned over and the fire-weather stations nearest the scene of the fire. This map also shows the location of the Wolf Creek fire,

FIGURE 1.—Northwestern Oregon—location of fire, where it started, area covered, and nearest fire-weather stations.

where it started and its proportional size as compared with the much larger Tillamook fire.

Relative humidities were generally low, 35 percent and lower, from August 10 to 16 at the lower interior stations, but for a somewhat longer time at the higher levels on the ridges. They were low again from August 21 to 26, this latter period producing lower humidities of longer duration and being by far the worst of the two periods. As regards relative humidity, the worst fire-weather days were as follows:

(a) Coast stations, ranging in elevation from 40 to 80 feet: Low humidities on August 14, 21–22, and 25, extending well into the night of the 25–26th. There was considerable recovery of relative humidity near the coast on the 23d, 24th, and 26th. (See fig. 3.)

(b) Valley stations, ranging in elevation from 70 to 750 feet: Low humidities on the 10th to 16th, the worst fire-weather conditions prevailing on the 14th and 15th. Humidities low again from the 21st to the 26th, the worst days being the 25th and 26th, not only for this critical period but also for the whole time the fire

was active. Relative humidities were quite low in the daytime but made considerable or complete recovery at night. (See fig. 3.)

(c) High ridge stations, ranging in elevation from 1,140 to 3,153 feet: Humidities generally low from the 10th to the 17th, and again from the 21st to the 26th. Humidities quite low all night of the 14-15th, the 22-23d and the 25-26th. Highest relative humidity at Mount Hebo lookout during the entire period of the 21st to the 26th was 50 percent. Highest relative humidities the night of the 25-26th were as follows: Mount Hebo lookout, 26 percent; Cochran (C. H. Wheeler Camp No. 9), 31 percent; Tidewater Timber Co., 33 percent; and Black Rock Camp (Willamette Valley Lumber Co.), 39 percent. (See fig. 3).

(d) Lower Columbia River: Low relative humidities prevailed on the 12th, 14th, 21st, and 22d, and 25th and 26th.

(e) Columbia River Gorge: Low relative humidities prevailed on the 15th and 16th, and again from the 21st to the 26th, the worst coast stations again on the 25th, continuing low well into the ensuing night; however, they were not nearly so low as on the 21st and 22d.

Table 1 shows the departure of daily lowest relative humidity of 2-hour duration from the mean for August at the fire-weather stations nearest the Tillamook fire during the whole period the fire was most active. In general, the departures were more extreme at the high ridge stations, also at the coast stations on the worst days, than at the valley stations. Large departures, however, were experienced at all stations in the two periods when the fire spread most rapidly. The most extreme departures were at the coast stations on the 14th,

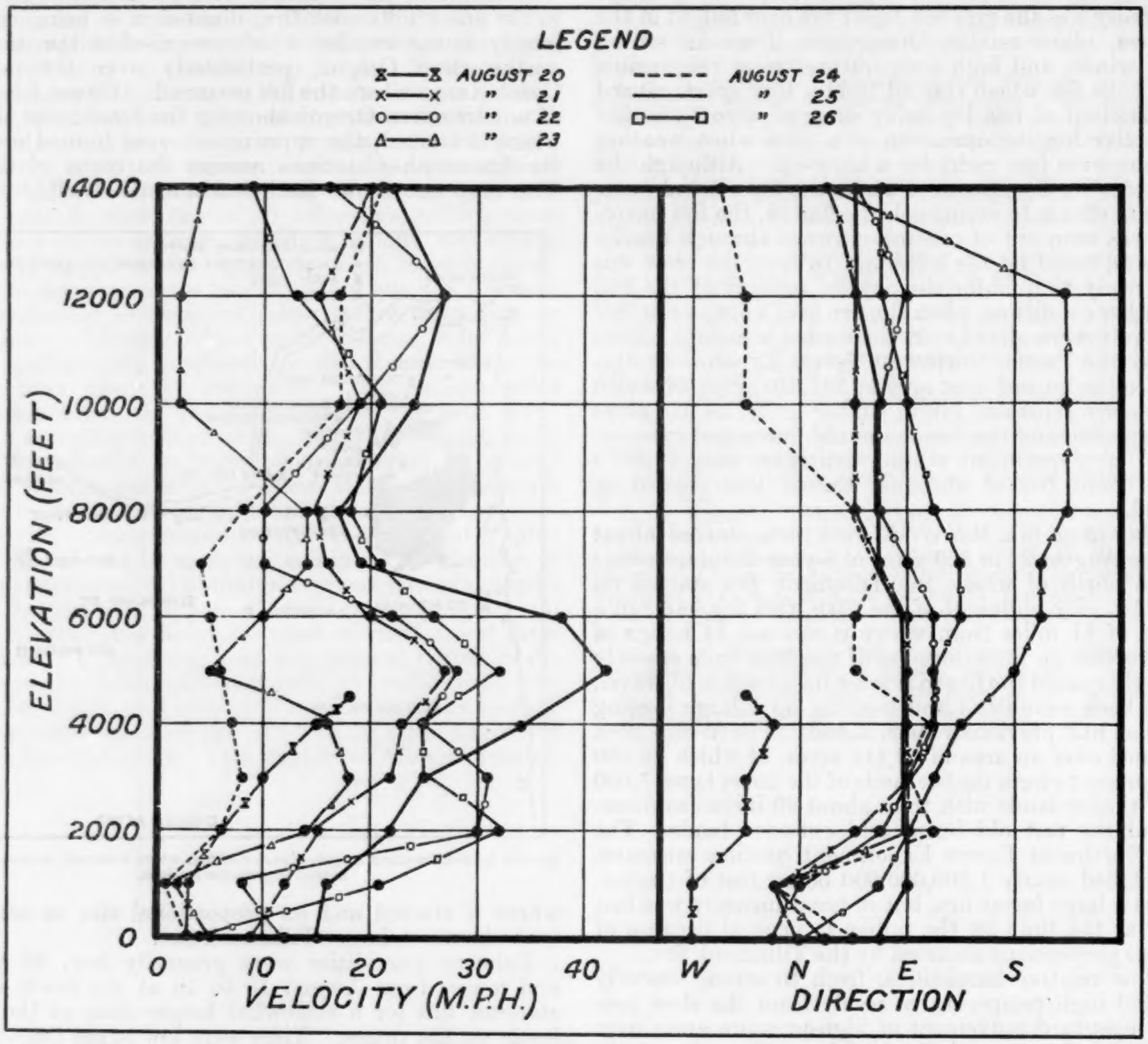

FIGURE 2.—9:30 a.m., August 20-26, 1933 pilot-balloon runs, Swan Island, Portland, Oreg.

days being the 25th and 26th. Scarcely any recovery of relative humidity on August 24 although there was some decided recovery at many of the valley and high ridge stations on this date.

Relative humidities were quite low at the valley stations in the daytime during these critical periods, but were high and made complete or almost complete recovery at night. They made much less recovery at night at the higher ridge stations, and little or none at all on the dates when the fire spread rapidly, or "blew up" entirely. Relative humidities were quite low at coast stations only on the 21st and 22d. Relative humidities were low at 21st, and 22d, and at valley and high ridge stations on the 14th, 15th, 22d, 25th, and 26th. The relative humidities were above the average, in general, during the period of August 17 to 20, when the fire was quiet and spread very slowly. The total number of hours the relative humidity was 35 percent, and lower, at each station for each of the two periods, is also given in this table.

The low relative humidities of these two critical fire-weather periods, as in all critical fire-weather periods of western Oregon, are largely the result of winds from the

north and east with force considerably above normal. The normal prevailing wind direction during the fire-weather season in the northern Coast Range is from north and northwest with a relative humidity that is normally high at night and moderately high in the day-time. Easterly winds are of only occasional occurrence during the summer months over the northern Coast Range but, coming from warmer, continental areas, are warm, dry, desiccating winds that result in critical fire-weather periods with low relative humidities. The greater the force of these easterly winds, and the longer their duration, the greater the fire hazard becomes in the timbered areas.

Northerly winds, with an easterly component in the morning, prevailed over the northern Coast Range from the 10th to the 16th, except on the 15th when the wind was from the east both night and day. Easterly winds prevailed almost continuously from early in the morning of the 21st until the evening of the 26th. Most of the time in these two periods, and particularly in the latter, wind velocities were generally fresh to strong in force (19 to 38 miles an hour), probably of gale force (39 to 54 miles an hour) at times, up to elevations of about 5,000 feet, above which level they usually diminished in force for some distance in elevation before increasing in velocity again. Figure 2 is here presented to show this tendency of the wind, being a graphical presentation of the daily 9:30 a.m. pilot balloon runs taken at Swan Island Airport, Portland, Oreg., from August 20 to 26 and showing the wind direction and velocity in miles per hour from the surface to an elevation of 14,000 feet. The Columbia River Gorge is largely responsible for the increase in velocity of these easterly winds from the surface to an elevation of approximately 5,000 feet, above which level the velocity decreases materially. The Gorge acts as a funnel through the Cascade Range through which the easterly winds at such times are poured with increased force over the extreme northwest counties of Oregon where the fire occurred. Wind velocities normally increase in force with increase in elevation above the surface of the earth. Wind velocities were highest on the 14th, 15th, 21st, 22d, 25th, and 26th, being terrific the latter 2 days when the fire spread most rapidly and did the most damage.

Table 2 shows the highest wind, in miles per hour, recorded daily at a number of stations in northwestern Oregon. The location of each station with reference to the fire is shown on figure 1. North Head is near the mouth of the Columbia River on the Washington side. Baker Point, Mount Hebo, and Prairie Mountain are forest fire patrol lookouts in the northern Coast Range. Portland is in the northern end of the Willamette Valley south of the Columbia River. Highland Butte and Green Peter are association lookouts on or near the western slope of the Cascade Range while Mount Wilson is a Forest Service lookout on the summit of the Cascade Range about 20 miles south of Mount Hood. Crown Point is an airways station at the mouth of the Columbia River Gorge. With the exception of three hours after midnight at Crown Point, wind velocity records are complete for each hour at North Head, Portland, Mount Wilson, and Crown Point from midnight to midnight, while the records at each of the other stations are only during the daytime as indicated. Records at Crown Point also show the wind was from the east from 5 a.m. to 2 p.m. on the 15th, from 5 a.m. on the 21st to 1 p.m. on the 23d, and from 8 p.m. on the 24th to 10 p.m. on the 26th, also that the wind was gusty from 5 a.m. to 1 p.m. on the 25th and again from 10 a.m. to 5 p.m. on the 26th. The prevailing winds through the Columbia River Gorge are normally from the west.

Figure 3 is a graphical representation of wind velocity and direction at the two wind recording stations nearest the fire during the time it was most active. The location of these stations with reference to the fire is shown on figure 1. The legend thereon explains the graphs. Arrows representing the wind direction for each observation are shown along the top of each graph, and fly with the wind. Dots representing the wind velocity for each observation are shown near the bottom of each graph, and are connected up with solid lines to show the daily trend. Legends showing when the fire started, the days on which it spread more rapidly or more slowly, or not at all, and the final "blow-up" when the greatest damage was done, have also been placed along the bottom of figure 3. On close inspection of the humidity, wind direction and velocity it is readily seen the fire spread most rapidly and did its greatest damage when relative humidities were quite low coincident with the occurrence of fresh to strong easterly winds.

Periods of wind with considerable force, such as occurred during the time this fire was most active, are not of unusual occurrence in the Coast Range. Their most frequent directions, however, are from westerly sources with relative humidities high or moderately high so that serious conflagrations do not then occur.

Temperature is not so vital a factor in critical fire-weather periods as relative humidity and wind, being important only in its action on the relative humidity. The periods of low relative humidity are usually coincident with the periods of higher temperature. Temperatures were above normal from the 7th to the 18th, considerably above from the 10th to the 16th and decidedly above from the 13th to the 15th. Temperatures at Portland for these periods averaged 6° and 9° above normal, respectively, for the first two periods, and were 10°, 11°, and 17° above normal, respectively, on the 13th, 14th, and 15th. The maximum temperature at Portland on the 15th was 102°, being 4° higher than the former high record for the month. Temperatures were above normal again from the 21st to the 26th, averaging 8° above at Portland and being 10° above the 22nd, 25th and 26th, and 12° above on the 23d. Some other high temperature records were also established for the month at other western Oregon stations on the 15th.

The average monthly precipitation of western Oregon for August was 0.63 inch, a departure of −0.15 inch from the normal. Good rains were general over the State on the 3d and 4th. Light scattered rains occurred over the northern part of the State on the 19th, and good general rains over the western portion on the 29th and 30th.

Since the special fire-weather service of the United States Weather Bureau was started in Oregon and the Pacific Northwest late in the 1924 season, there have been four outstanding critical fire periods in western Oregon. The first of these periods occurred September 3 to 16, 1929, the second April 18 to 28, 1931, the third October 3 to 10, 1932, and the fourth that of the past season in August, from the 21st to the 26th. Similar meteorological factors—low relative humidities, fresh to strong easterly winds and high temperatures—were responsible for each of these hazardous periods. The first and third periods followed protracted dry spells and resulted in big forest fire losses. The second period was the most severe of all, as humidities were quite low and of long duration, and winds were of considerably greater intensity than in the other periods. Forest fire losses were low, however,

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as it followed immediately upon the heels of heavy rains and snows through March and April until its inception. Considerable standing timber was blown down in the northern Cascade Range and the forests of the State were littered with broken twigs and other debris, creating a humidities are also consistently of longer duration at the higher levels than at the lower levels at these times, because air circulates more freely and there is less range in temperature at night at the higher levels on the ridges than at the lower levels in the valleys.

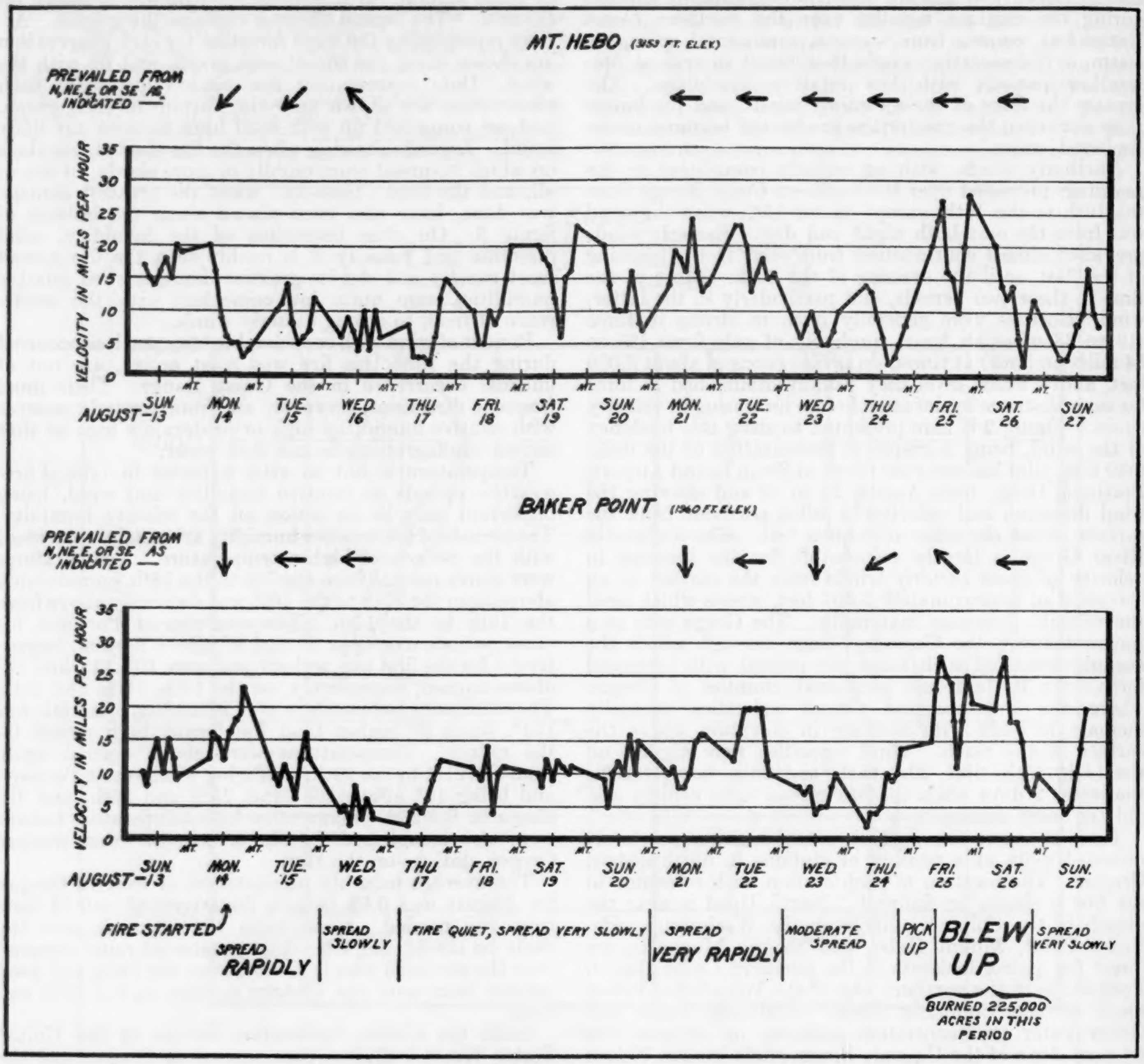

FIGURE 3.—Wind velocities and directions at stations nearest fire.

high potential fire hazard throughout the ensuing season. The fourth period and its attending results have already been discussed previously in this article. Winds increase normally in velocity with increasing altitude, but the highest winds in each of these critical periods were in the lower atmospheric levels up to 5,000 feet. Low relative

Other historic forest fires have occurred in western Oregon and the Pacific Northwest in the past, concerning which little is known aside from their location and size. There is little doubt in the mind of the writer, however, that the same meteorological factors, a combination of low relative humidities, easterly winds and high tempera-

tures, so vital in the propagation of the Tillamook fire, were also big factors in the spread of these other large fires. Then, too, there were no organized agencies in those days for the prevention and suppression of forest fires, so it is likely they became much larger than would be possible under the efficient present-day methods for prevention and suppression. The weather in the northern Coast Range from August 21 to 26, particularly on the 25th and 26th, when the greatest damage was done in the Tillamook fire, was extremely bad and most likely as bad as any that had ever previously existed. Except for this one bad fire and the Wolf Creek fire, the protective organizations of Oregon and the Pacific Northwest enjoyed one of the best seasons in the history of organized protection in 1933.

TABLE 1.—*Highest daily wind velocity recorded at certain stations in northwestern Oregon during the 2 critical fire-weather periods in August 1933*

Stations	10th	11th	12th	13th	14th	15th	16th	21st	22d	23d	24th	25th	26th
North Head, Wash.[1]	28	27	26	26	22	20	17	18	20	15	16	17	18
Baker Point	12	17	20	15	23	16	6	16	25	10	14	30	28
Mount Hebo	11	14	24	20	20	14	10	24	25	13	14	28	20
Prairie Mountain	12	13	24	18	18	5	10	20	22	10	6	25	10
Portland [1]	11	13	15	15	13	11	9	15	17	8	10	19	16
Highland Butte	6	8	8	12	10	15	6	20	24	8	10	34	20
Green Peter	10	13	13	17	7	13	10	21	26	10	10	30	27
Mount Wilson [2]	16	20	21	20	19	23	19	36	39	22	34	43	31
Crown Point [3]	8	10	8	8	9	24	8	26	24	23	18	39	32

[1] Maximum wind during day, midnight to midnight, for period of 5 minutes.
[2] Highest average hourly velocity for day, midnight to midinight.
[3] 5 a.m. to 1 a.m.
Records at other sations are for daytime only, ranging from 6 or 7 a m. to 7 or 8 p.m.

TABLE 2.—*Departure of daily lowest relative humidities of 2-hour duration from the mean for August at the fire-weather stations nearest the Tillamook fire during the period the fire was most active in August 1933, also number of hours the relative humidity was below 35 percent for each of the 2 periods at each station*

	Mean	10th	11th	12th	13th	14th	15th	16th	17th	18th	19th	20th	21st	22d	23d	24th	25th	26th	27th	Number of hours, 35 percent, and lower	
																				10–16	21–26
VALLEY STATIONS																					
Youngs River	56	0	−3	−14	−12	−27	−17	−9	......	+2	+2	−5	−33	−35	−18	−8	−36	−29	+16	6	32
Jewell	50	−7	−7	−17	−20	−26	−22	−11	−11	−2	−5	−7	−28	−33	−33	−25	−34	−33	+26	18	47
Oregon-American	52	−18	−19	−22	−22	−28	−31	−12	−11	+3	+13	−5	......	......	......	......	......	......	......	28	......
Vernonia	44	−9	−11	−14	−15	−19	−25	−5	−1	+5	+14	−8	−19	−27	−24	−16	−27	−27	+24	29	52
Clark and Wilson	46	−6	−10	−11	−11	−17	−29	−9	−5	−4	+9	−10	−23	−28	−23	−19	−26	−26	+18	18	56
Forest Grove	40	−9	−12	−14	−17	−18	−17	−12	+7	0	+9	−7	−17	−18	+1	−11	−19	−18	+25	48	49
Portland	44	−9	−1	−12	−7	−8	−15	0	+15	+12	+6	+1	−9	−23	−20	−7	−25	−25	+23	14	52
Herman Creek R.S	41	+8	+1	+4	+6	+3	−23	−8	+5	+5	+5	+6	−13	−18	−19	−21	−19	−20	+6	11	51
HIGH RIDGE STATIONS																					
Tidewater Tbr. Co	53	−8	−10	−18	−17	−29	−23	−9	−6	+2	+5	−6	−33	−33	−30	−23	−29	−28	+24	15	69
C. H. Wheeler	48	−15	−18	−16	−17	−22	−23	−5	−3	+3	+15	−8	−23	−28	−28	−15	−22	−20	+23	38	88
Brix Logging Co	51	−9	−10	−12	−14	−17	−25	+4	−19	+18	+8	+11	−23	−28	−23	−16	−26	−27	+15	10	83
Mount Hebo Lookout	58	−19	−11	−13	−23	−35	−32	−23	−28	+20	+24	+5	−31	−36	−35	−23	−33	−37	+2	87	136
Black Rock Camp	47	−4	−12	−14	−16	−19	−11	−15	−7	+3	+3	−11	−17	−22	−17	−11	−17	−19	+11	36	65
Green Peter Lookout	49	−22	−26	−40	−29	−30	−33	−23	−6	−3	+21	−3	−25	−34	−29	−19	−35	−27	−1	66	114
Mount Wilson Lookout	42	−13	−21	−24	−22	−21	−20	−22	−12	+5	+42	+18	−8	−11	−19	−10	−7	−8	−19	120	32
COAST STATIONS																					
Nehalem	64	−7	−15	−11	−10	−17	−5	+4	−6	+4	−3	−17	−51	−48	+8	+17	+8	−9	+18	7	20
Hebo	62	+10	+2	+1	+5	−12	−5	+3	+8	+6	−7	−9	−24	−40	+20	+13	−32	+4	+14	2	23

LONG-PERIOD FLUCTUATIONS OF SOME METEOROLOGICAL ELEMENTS IN RELATION TO CALIFORNIA FOREST-FIRE PROBLEMS

By LESLIE G. GRAY

[Weather Bureau Office, San Francisco, Calif., June 1934]

Weather is a very important factor in the starting and spreading of forest fires (1) (2) (3). Each weather element affects fire behavior in different ways of varying importance. At present, the forester takes advantage of short-period daily, day-to-day, and seasonal weather changes in carrying on his work of fire prevention and suppression, and is further aided by short-range forecasts by meteorologists. However, the forester is handicapped in planning a long-period forest protection policy, budgets, and administration by lack of foreknowledge of long-period weather sequences—ignorance as to what to expect from trends of given types and to what extent long-period fluctuations in specific weather factors have affected or will affect his fire problems. The purpose of this paper is to present in a preliminary way the facts obtained by an extensive compilation of California data, and to note the inferences drawn by various students of weather sequences, expressed in terms of the forester's fire problem. It should be emphasized here that this discussion deals with recorded data, and indicates furture prospects only to the extent that we may justifiably assume that the "before" and "after" pictures will be the same or similar.

The various weather factors are expressed as mean values for the State of California, using for each item a homogeneous body of data from selected stations. For comparison purposes, other hydrological and related data, mostly from other than Weather Bureau sources, are used as supporting evidence. The principal graphical method used for presenting the data is that of accumulated departures from normal or average, or residual mass curves, the computation and meaning of which are explained by Barnes (4) and Marvin (5). Briefly, accumulated departures are well adapted for showing secular sequences, trends, or changes without distortion of the actual data. The method accomplishes natural smoothing without obscuring the real values. Where the graph shows a rise, values have been above average; where it shows a fall, values have been below average; and where it is horizontal, values have been exactly average. E. H. Bowie visualizes accumulated departures as representing a sort of bank account between the State of California and nature.

Nature makes deposits to the credit of California, which are drawn against naturally and by human use, the accumulated departure curve at any time showing the existing bank balance. During a series of exactly normal precipitation years, for example, there are no departures, and the graph is the single horizontal zero plotting or normal line. In a series of supernormal years, however, deposits are heavier than withdrawals, and the balance increases. In subnormal years, withdrawals exceed deposits, and the balance to California's credit is reduced.

Figure 1 shows mean precipitation values for California, adjusted to a 100-station standard. The 100 stations are geographically well-distributed, and in numbers proportional to the percentage of the total State area within given elevation zones, as follows: Low level, less than 500 feet, 21 stations; foothill level, 500 to 2,500 feet, 34; intermediate level, 2,500 to 5,000 feet, 23; high level, over 5,000 feet, 22.

Records are practically complete for the period 1911–30 for all of the 100 stations. Means for the different elevation zones during these 20 years show minute qualitative

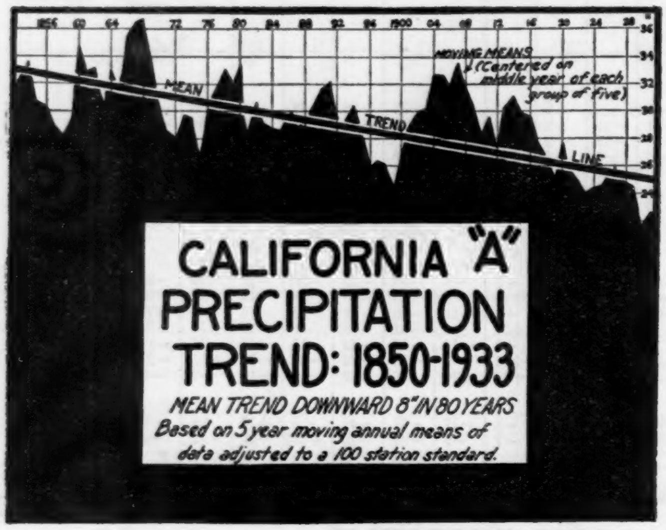

Figure 2a.

agreement from month to month, differing only quantitatively, since the higher zones have the larger means. Percentage relations between various combinations of stations and the 100-station mean for this period, worked out by months, were used to reduce the records for the varying number of stations extending back to 1850, to the 100-station standard. The final means are believed to represent practically a reliable and homogeneous body of data, giving approximately true relative precipitation differences from year to year, although not representing, necessarily, the real total amount of precipitation over the entire State area.

The actual mean seasonal precipitation (July–June) since 1850–51 in figure 1 shows an apparent downward trend. The next graph shows departures from average, and clearly brings out the decreasing variability of California precipitation as the seasonal means decrease. The next section shows accumulated departures, illustrating the long-period sequences or swings in series of dry and wet years, not readily perceptible from the other graphs. In general, California received more than its 84-year normal rainfall up to 1890. Then there were short downward and upward trends, and, finally, a steady decrease since 1916, the decrease being much faster than the original accumulation. The lower section, giving moving 5-year annual means, illustrates the long-period downward trend in the annual mean. Similar moving means of sunspot numbers show no clear-cut relationships.

Figure 2 deals further with precipitation. Section "A" shows the downward trend in annual means more clearly by exaggerated scale, the trend being of secular nature and amounting to about 8 inches in 80 years, or at a rate of about 0.10 inches per year. Section "B" shows single and double curved trend lines fitting the data somewhat more closely. Analysis of possible cycles is not within the scope of this paper, but it may be pointed out that successive harmonics of the trends would result in a series which, added algebraically, would correspond with the original curve.

Streiff (**6**) mentions that Marvin found 24 possible harmonic elements in precipitation data, Baur 20 in temperature and Michelson 33 in sunspot numbers. The multiplicity of cycles, periodicities, and sequences apparently discovered in various data by many investigators has led to doubts in some quarters as to the reality of definite periods. Some regard apparent regular cycles as fortuitous. Others recognize numerous influences at work which, conceivably, may be related to apparent complex harmonies. This view holds that some alleged periods are not fundamental, but represent reinforcements or interferences of cycles of varying length or amplitude or both. The effect is a series of more or less irregular waves in the plotted crude data.

However, in section "A", a definite symmetry of values with reference to the mean trend line is observable about the year 1886. Notice the close qualitative correspondence between the various peaks and depressions extending both ways from 1886. Details are shown in section "B." With some differences of 1 or 2 years in the number to right and left of the year of symmetry, possibly due to displacements caused by the moving means method employed, details of the comparable numbered peaks and depressions of section "B" appear in table "C" It is a singular fact that the mean year of symmetry agrees *exactly* when calculated separately from maxima and minima. Barnes (**4**) found an identical year of symmetry for English rainfall, describing his findings in the following words: "The balance about a certain center is particularly noticeable . . . the center at first sight appearing to occur at the end of 1884 if *short* equal periods are taken on either side . . . But . . . dry years subsequent to that date were more in number than wet years preceding it . . . hence, for *long* periods the center becomes displaced to the end of 1886." His data were plotted in terms of accumulated departures, and not directly, as for the California data.

Investigating the matter further, a 203-year rainfall record for selected English stations compiled by Alter (**7**) was plotted in chart "D" by moving 5-year means, Barnes' data were included and the California data added. The curves apparently indicate a very perfect symmetry of English rainfall around 1829, from 1803 to 1856, in the actual data, 26 and 27 years on each side of 1829, respectively. The data also show symmetry in terms of *accumulated departures* about the years 1886 and 1772, the first well-marked and extending from 1856 to 1916, and the other rather imperfect, and extending from about 1741 to 1803. California data show direct value symmetry about the year 1886. The data seem to show wave interference phenomena already mentioned. If extended symmetries actually occur, they form a ready means of projecting sequences ahead, given sufficient

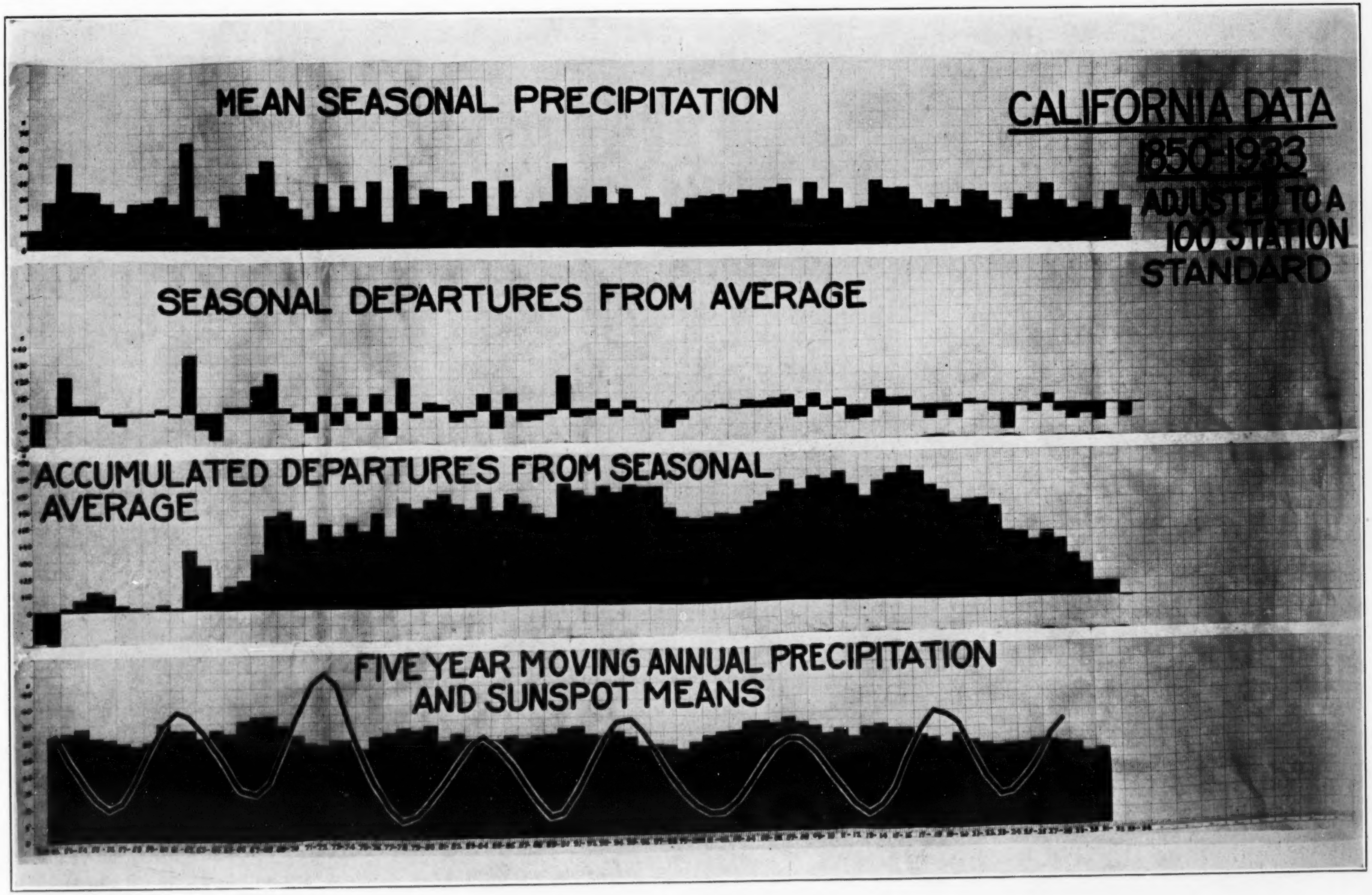
MEAN SEASONAL PRECIPITATION
CALIFORNIA DATA
1850-1933
ADJUSTED TO A
100 STATION
STANDARD
SEASONAL DEPARTURES FROM AVERAGE
ACCUMULATED DEPARTURES FROM SEASONAL AVERAGE
FIVE YEAR MOVING ANNUAL PRECIPITATION
AND SUNSPOT MEANS

FIGURE 1.

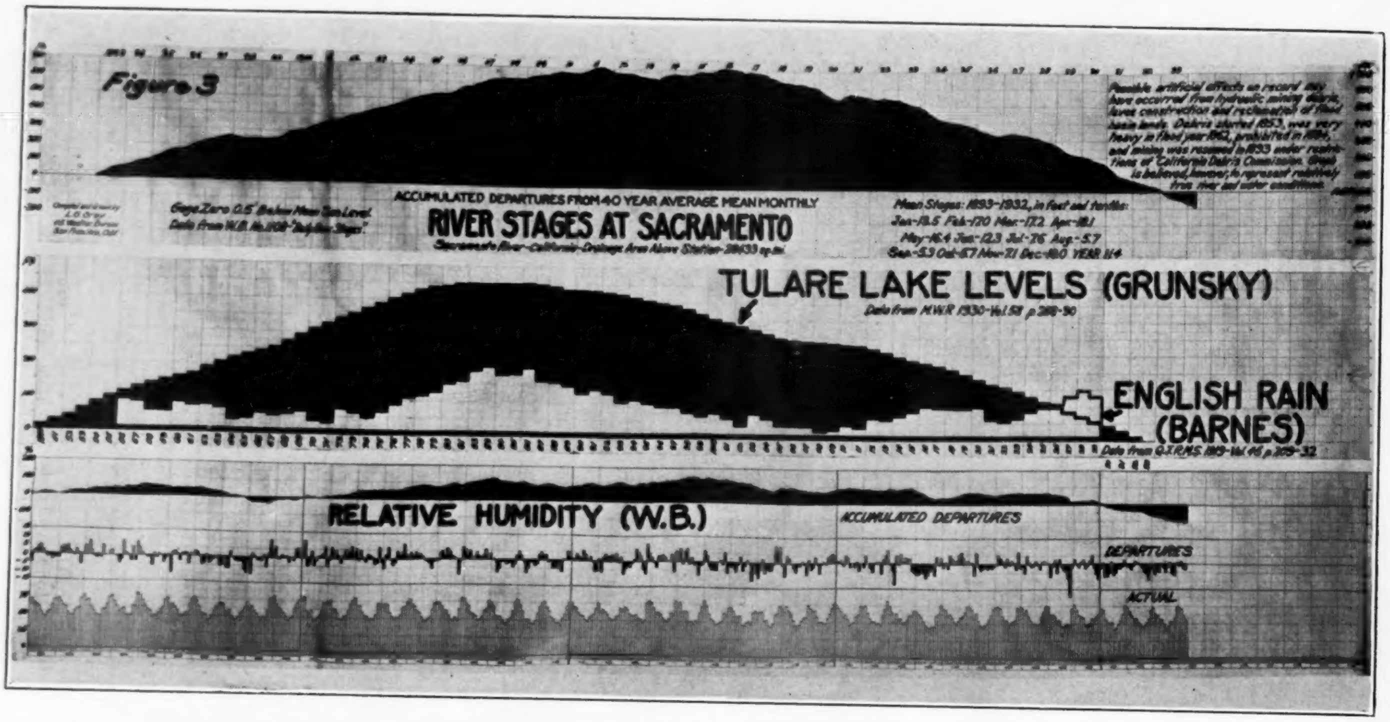

FIGURE 3.

FIGURE 4.

back data, and eliminate the labor and difficulties involved in disentangling fundamental periods. A symmetry of precipitation about the year 1903 has been found for Algeria. Recent German investigations have shown pronounced symmetries of barometric pressure for short periods. Further study of precipitation symmetry is warranted, even though definite use of symmetries in anticipating future conditions is not yet, and may not be, possible.

Figure 3 presents hydrological data confirming the downward trend in precipitation already mentioned. River stages at Sacramento show a peak in 1916 and a steady subsequent decline, supporting the precipitation peak of 1916. Tulare Lake levels show a maximum in 1886, agreeing with the English rainfall data, given below for comparison. The lower section shows weighted relative humidity means for 11 Weather Bureau stations,

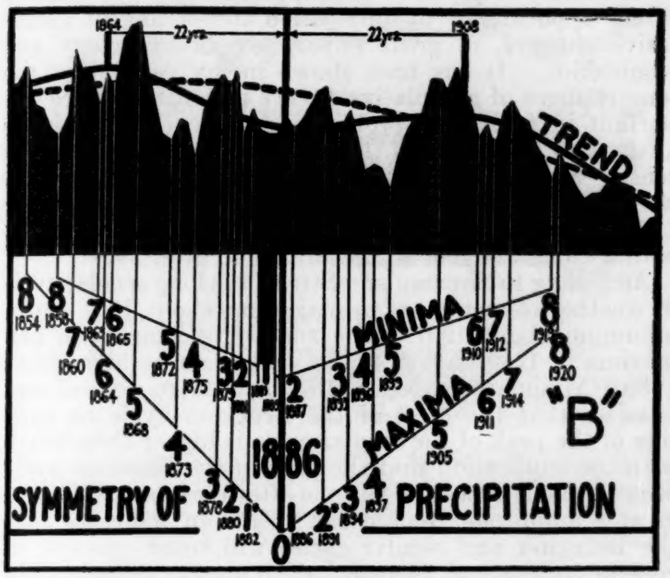

Figure 2b.

by months, since 1891, comparing the different methods of presentation and showing a confirming downward trend since about 1915. Figure 4 shows full natural run-off from the Sacramento-San Joaquin drainage basin, confirming the precipitation data in terms of downward trend since 1916. Similarly, water levels in wells in the San Joaquin Valley have dropped rapidly since 1917, the difference amounting to 48 feet in 18 years. The steep rate of decrease is due, apparently, to the excessive drain on stored underground waters by pumping made necessary by the current series of dry years.

State means of temperature were plotted in the lower portion of the figure, but show discordant results, which are connected with the progressive increase in elevation of stations used in determining the mean. The 11 Weather Bureau stations used for relative humidity show more consistent results. To further check the temperature trend, 11 cooperative stations were selected, and their combined trend agrees satisfactorily with the Weather Bureau stations, although trending upward during the first 10 years. Temperature has been below average from 1891 to 1923, and has since been above average with a much steeper cumulative trend.

Figure 5 shows all weather elements plotted simultaneously, so far as possible using the record for the period 1900–33. Vapor pressures show downward trend in general since 1914; temperature a marked upward trend since 1923; and evaporation, being a net result of several influences, is erratic, but on the whole trends upward since 1923. Snowfall data show a downward trend since 1923, and snow depths April 1 show an even more marked drop, beginning with 1922. Thunderstorm days show a fairly regular downward trend since 1918, and lightning fires a marked upward trend since 1922, leveling off in 1925. In this case, the greater liability to fire-start due to decreasing precipitation and consequent forest fuel dryness about balances the lesser chance for lightning fires due to decreasing numbers of thunderstorm days. Wind velocity, adjusted to an uncorrected 4-cup anemometer basis, appears to show a more or less regular 22 year sequence, although the record is too short to be certain. The regularity is hard to explain as accidental.

	MINIMA		"C"	
		MEAN MID-YEAR		
1	1883	1884.0	1885	2
2	1881	1884.0	1887	6
3	1879	1886.0	1893	14
4	1875	1885.5	1896	21
5	1872	1885.5	1899	27
6	1865	1887.5	1910	45
7	1863	1887.5	1912	49
8	1858	1888.5	1919	61
No.	Year	1886.06	Year	Yrs.
	MAXIMA			
1	1882	1884.0	1886	4
2	1880	1885.5	1891	11
3	1878	1886.0	1894	16
4	1873	1885.0	1897	24
5	1868	1886.5	1905	37
6	1864	1887.5	1911	47
7	1860	1887.0	1914	54
8	1854	1887.0	1920	66
No.	Year	1886.06	Year	Yrs.

Figure 2c.

Fortunately for fire protection, wind velocity has trended downward during the bad fire years since 1924. Wind velocity shows a very close relation to fire areas, the total burned acreage decreasing to 1916 with about normal wind and supernormal precipitation, but increasing as the wind increased thereafter to and including 1924, when the rate of increase was accelerated by increasingly subnormal precipitation and high temperatures. The leveling off of the burned acreage trend after 1926 seems to be due primarily to decreasing wind movement, since the precipitation and temperature trends continued to be unfavorable, although temperature leveled off somewhat in 1931 and later. The percentage of sunshine for the 11 Weather Bureau stations has increased since 1916, bears a nearly perfect inverse relationship to the number of cloudy and rainy days, and all three agree remarkably well with the precipitation trends. Relative humidity has trended downward since 1922 and agrees in general features with the precipitation.

From regional summarizations furnished by the United States Forest Service, data computed and plotted in the lower portion show that forest fires in the national forests of California decreased from 1908 to 1912, and then increased at a fairly steady rate, in a cumulative sense, until 1925, when the number leveled off. This is true both of lightning and man-caused fires. Total burned acreage decreased from 1908 to 1916, trended slightly upward to 1923, and then steeply upward to 1925, after which it leveled off. Apparent improvements in protection organization and technique seem to be shown by the trends of average burned area per fire, which has trended downward somewhat in recent years in spite of more unfavorable conditions, and at a more rapid rate than either number or total area of fires. Suppression costs and damage to forest values parallel one another, and show rather smooth downward trends to 1923, upward trends to 1931, and a leveling off thereafter. The snowfall accumulation is plotted for comparison, and shows a fairly good inverse relationship to costs. Temperature, however, shows practically a direct relationship in all particulars to the trend of costs. Snowfall seems

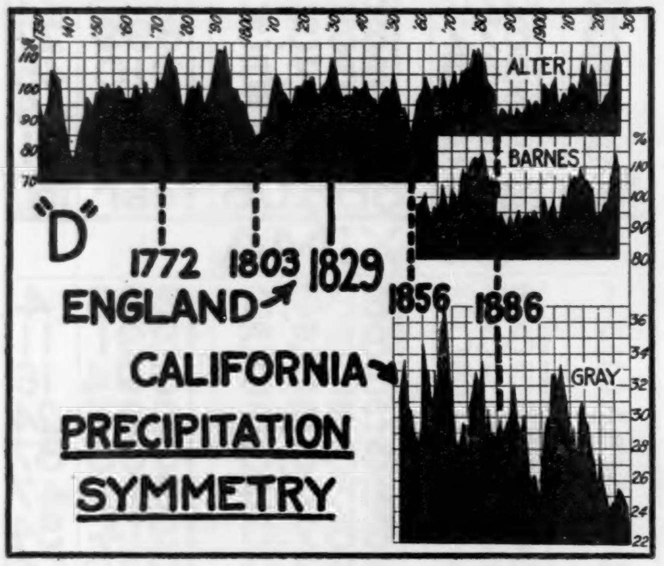

FIGURE 2d.

to be a combining factor, integrating the effects of both temperature and precipitation.

It is believed that the foregoing has demonstrated the truth of the following statements:

1. Long-period weather sequences occur in California, in numerous individual meteorological and hydrological factors or elements.
2. Long-period fluctuations are apparent also in forest-fire data.
3. The weather trends are responsible, primarily, for fluctuations of fire numbers, areas, and costs, and are important not only over short periods, as is generally recognized, but also over long periods, including those of secular nature. The precipitation trend is the single one most closely connected with all others.
4. All trends, in general, have been toward more unfavorable conditions for fire prevention and suppression, especially since 1916 for some elements, and since 1923 for practically all others.
5. The accumulated departure method employed in this paper appears to more effectively bring out secular trends, and clearly shows the importance in California forest-fire problems of cumulative as opposed to temporary influences.

With reference to our current position in terms of long time weather sequences, and future prospects, I shall summarize the opinions of several authorities and students of cyclic phenomena, for what they may be worth. Streiff (**6**) believes that about 1940–50 the precipitation may have again increased about 30 percent to values prevailing around 1880. He has determined a secular sunspot cycle apparently similar to the precipitation sequence, and supports it with precipitation data for the eastern and western United States, and Sequoia tree ring data. In another article (**8**), he points out that the Brückner cycle minimum occurred in 1929, and that a maximum is due around 1939. The longer secular cycle, he thinks, should reach a maximum around 1945–50. A previous minimum of this cycle occurred in 1905 and a maximum in 1875. Previous lengths of the secular cycle have been 70, 60, and 90 years, an average of 73 years. During the Brückner cycle minima, dry and warm years are frequent, and during maxima, wet and cool years predominate. He emphasizes the lack of applicability of his data to short-term forecasting of momentary changes, as is usually required of practical meteorology, and the direct applicability to long-period forecasting of cumulative changes, of great importance in hydrology and engineering. It has been shown in my paper that the long changes of cumulative nature in California are important in forest fire problems, and hence there is an analogy to hydrology in the long-time policy or planning sense. Shuman (**9**) agrees with Streiff, and gives data showing river discharges in Michigan with maxima in 1935 and 1939, and with minima in 1931 and 1937, but with a moderate general upward trend after 1931.

According to Shuman and Streiff, the long secular cycle in weather elements had a maximum about 1851 and a minimum about 1907. The sunspot secular cycle had maxima in 1780 and 1856, and will again be high about 1950. Minima occurred in 1816 and 1906. Streiff emphasizes that the crest of the Brückner cycle on each side of the peak of the secular cycle is higher than usual, with the implication that the peak of the Brückner cycle prior to about 1950, and the one after that date, will have greater amplitude than usual. Shuman indicates that the Brückner and secular cycles will trend upward, in general, until about 1950–52. The present drought situation over a considerable portion of at least the Northern Hemisphere in middle latitudes, from his data, appears to be the result of coincidence of several cycles which happen to reach minimum or near-minimum values simultaneously. From correlations of Lake Ontario levels, he finds that levels will decrease to about 1934–5, and increase up to 1940, with the values for 1930–50 a little lower than for 1870–90.

Clough (**11**) believes that a series of mild winters are due about 1940, based on the combined effects of a Brückner cycle of 37 years (Streiff thinks the true Brückner cycle is 22.6 years) and an 83-year period. Based on a 275- to 300-year period, he believes that a warm and dry epoch will occur around 2000. Based on a 1,400-year period, he says:

> Evidently . . . in 75 or 80 years from now (2050?), or the second recurrence of the Brückner period, the near-coincidence of minimum phases of four periods will occur and as a result there are likely to be prolonged and disastrous droughts.
>
> The exceptional warmth and dryness of the past few years can only be explained as the result of the near-coincidence of the 37-year and 83-year epochs of minima, combined with the effect due to the relatively near approach of the longer periods. Of course, the Brückner period has the largest amplitude so that around 1950 or 1955 the weather will be considerably cooler and wetter than at present. However, it is probable that the present century as a whole will prove to be exceptionally dry and warm as compared with the past two centuries.

If the foregoing summarized statements are valid and if the internal evidence of California data, which are in

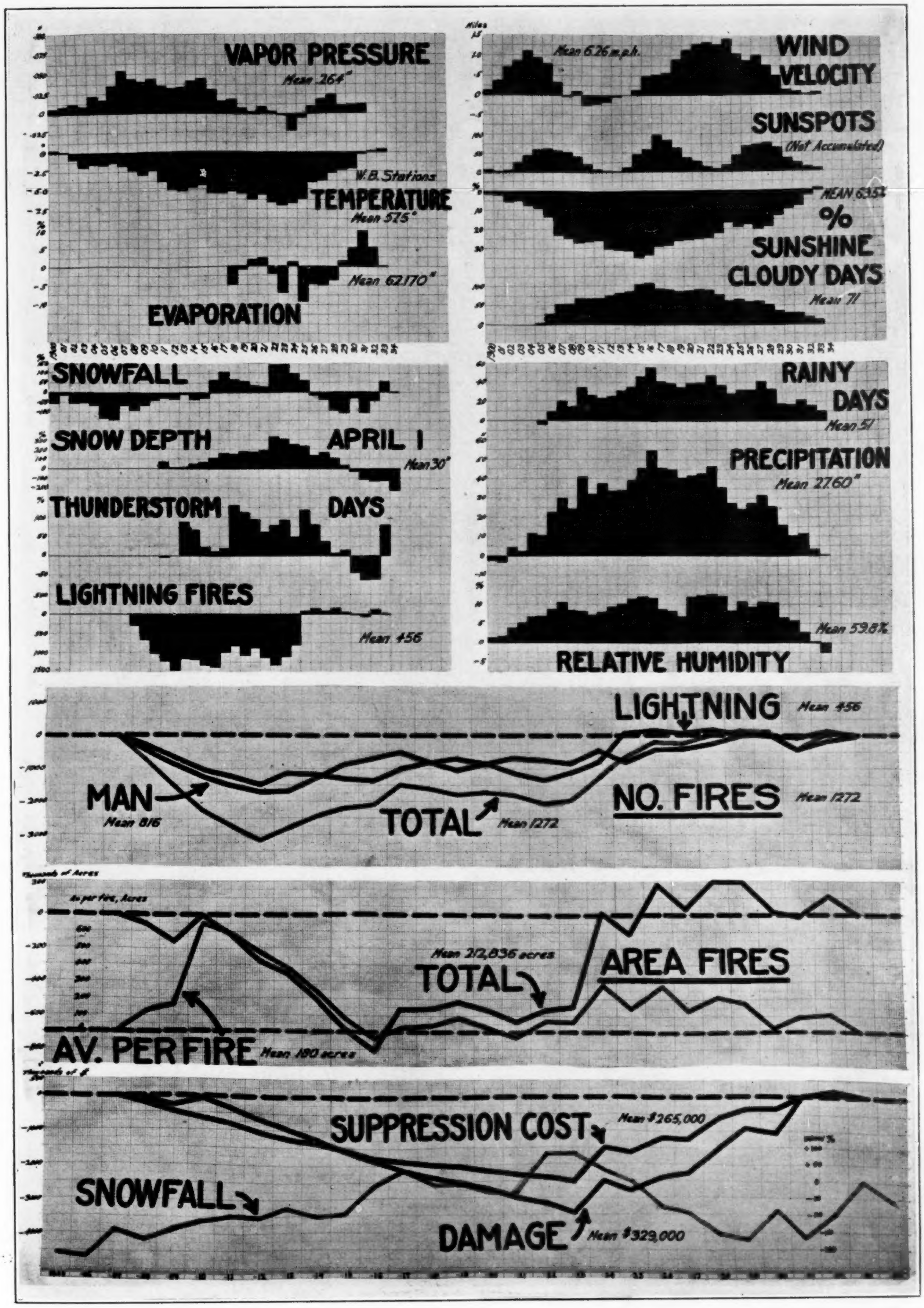
VAPOR PRESSURE
Mean .264"
TEMPERATURE
W.B. Stations
Mean 57.5°
EVAPORATION
Mean 62.170"
WIND VELOCITY
Mean 6.26 m.p.h.
Miles
SUNSPOTS
(Not Accumulated)
% SUNSHINE
MEAN 63.5%
CLOUDY DAYS
Mean 71
SNOWFALL
SNOW DEPTH APRIL 1
Mean 30"
THUNDERSTORM DAYS
LIGHTNING FIRES
Mean 456
RAINY DAYS
Mean 51
PRECIPITATION
Mean 27.60"
RELATIVE HUMIDITY
Mean 59.8%
LIGHTNING
Mean 456
MAN
Mean 816
TOTAL
Mean 1272
NO. FIRES
Mean 1272
Thousands of Acres
Av. per fire, Acres
Mean 212,836 acres
TOTAL
AREA FIRES
AV. PER FIRE
Mean 190 acres
Thousands of $
SUPPRESSION COST
Mean $265,000
SNOWFALL
DAMAGE
Mean $329,000

FIGURE 5.

general agreement with portions, at least, of the summarized statements have any reality, it may be inferred that appreciably less favorable conditions are probable in the near future, with noticeable upward trends beginning about 1930, reaching a maximum about 1950 to 1955, with the earlier date most favored as the center of the period, and with more severe conditions centering around the year 2050.

In conclusion, it is believed that the approximately correct long-period weather and fire sequences have been shown for California, their connections have been demonstrated in a cumulative sense, and the opinions prevalent concerning future prospects have been given, not as forecasts, but as the current thought on the data by competent students. Whether the picture "before" will prove to resemble the picture "after", or be something unexpectedly different, is uncertain. All we can confidently assert is that long-period secular swings take place and modify conditions over extensive time periods and areas, but individual years or series of years, and individual places, are subject to shorter sequences which by "interferences" make prediction uncertain as to definite turning points, places or conditions during any particular season.

LITERATURE CITED

(1) Show and Kotok: Forest Fires in California, 1911–20; An Analytical Study. U.S.D.A. Circ. 243. 1923.
(2) Same: Weather Condition and Forest Fires in California. U.S.D.A. Circ. 354. 1925.
(3) Same: Cover Type and Fire Control in the National Forests of Northern California. U.S.D.A. Bull. 1495. 1929.
(4) A. A. Barnes: Rainfall in England: The True Long-Average as Deduced from Symmetry. Quar. Jnl. Roy. Met. Soc. v. 45, 1919, p. 209–32.
(5) C. F. Marvin: Concerning Normals, Secular Trends and Climatic Changes. Mo. Wea. Rev. August 1923, vol. 51 p. 383–90.
(6) A. Streiff: Mo. Wea. Rev. July 1926, vol. 54.
(7) D. Alter: Mo. Wea. Rev. December 1933, vol. 61.
(8) A. Streiff: Mo. Wea. Rev. October 1929, vol. 57.
(9) J. W. Shuman: Mo. Wea. Rev. March 1931, vol. 59.
(10) H. W. Clough: Mo. Wea. Rev. April 1933, vol. 61.
(11) Same: Bull. Am. Met. Soc. March 1934, vol. 62.

LONG-RANGE FORECASTS IN PUERTO RICO

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Reference to the tables of monthly surface-water temperatures of the Caribbean Sea and Florida Straits, 1920–32 emphasizes their close correlation with the surface air temperatures of windward coast stations in the area. A comparison of the annual temperatures for the period gives a positive coefficient of 0.88 for the San Juan-Caribbean Sea relation and 0.60 for Key West and the Straits. A comparable example is given by Pettersson (1), a coefficient of 0.86 being obtained for the air temperature of Madeira and the surface waters of the North Atlantic, 35 miles distant, based upon the years 1900–13. At San Juan the thermometric exposure is near the ocean at an elevation of 53 feet above sea level, the prevailing winds being easterly off the water. There occurs a lag in the yearly maximum temperature of both the air and water until the late summer or fall months. Another similarity is the maintenance of positive or negative trends with respect to the normal, for long periods. During the 35 years, 1899–1933, sequences of 14, 18, 19, 21, 22, 23 consecutive months appear in the mean monthly air temperature records, periods having the same temperature sign. This persistency is apparently due to a combination of factors, primarily the marine type of climate, and the position of the Island with respect to the North Atlantic high pressure area, with the continuity of circulation attendant upon it. The ocean currents, induced by the trades likewise play a part, the North Equatorial current dividing at the eastern end of the Antilles, forming the northerly current of the Bahamas and the southerly, flowing into the Caribbean. A correlation value of 0.82 was obtained for the temperature at San Juan and at Georgetown, Demerara, stations touching the north and south portions of the Equatorial current, respectively.

To trace, if practicable, the cause of the changes occurring at periodic intervals in the temperature trend with respect to the normal, comparison was made of the variations in wind direction between NE. and SE. at the station. This failed to indicate any definite influence on the corresponding temperatures, thus bearing out the statement of C. F. Brooks (2) that in the Tropics:

> The effect of change in wind velocity is most noticeable, while changes in direction are of little or no effect. When the trades are unusually strong for a period, the warm layer of surface water is driven forward and concentrated in the Equatorial current, where it forms a plus departure in temperature. The place of the warm surface sheet is taken by cooler subsurface water, making a minus departure.

C. E. P. Brooks (3) writing of the NE. and SE. trades, as these winds relate to the volume of the Gulf Stream, and later to the temperature of North Atlantic waters, has estimated the average rate of movement of the North Equatorial current at 17 miles per day, or the time required to flow between 16°N/23°W. and 16°N/60°W., a distance of 1,900 miles, at approximately 112 days. On this basis we may estimate the time to arrive at the eastern end of the Antilles as about 128 days, or 4 months. This being only the average rate, which would vary with the strength of the trades, a lowering of the figure by as much as 25 percent or a whole month would not be unusual in years when conditions favored. To obtain a value reflecting the monthly variation in the movement of the trades, mileage totals at the station of the NE., E. and SE. winds (constituting approximately 85 percent of the total movement) were used. These were then related to the variation in temperature of ensuing months, the results revealing that months of marked trades activity are generally followed by a decrease in temperature within 3 to 4 months. An excess of mileage did not in itself represent the control, unless the winds were of higher than normal velocity. In the summer and fall months, frequently, there occurred an excess mileage which only represented a steady trades circulation, to the exclusion of other directions, but with no exceptionally high velocities. At this season, too, the waters having been warmed to a greater depth, proportionately stronger winds become a requisite to induce a deep drift current, if temperature changes are to be effected. Such winds are generally lacking. The normal velocity of 15 miles per hour does not produce any marked disarrangement of the temperature gradient of the ocean (W. Ekman). Velocities in excess of this rate occur most frequently (80 percent of the total) in the months of November and December and January to April, a period of the year when the waters are warmed to the least depth. With this fact, it is not unexepcted to find a considerably higher correlation value resulting from the first and fourth quarter wind movement than in the second and third quarters (table 1). There is no indication, however, of a preliminary rise in temperature, mentioned by

Brooks (2) (3) with reference to temperatures of the Gulf Stream. A rise in temperature, when it occurs, is found to be related more directly to weak trades, and is generally accompanied by minus pressure departures. The negative deviation, on the other hand, follows increased trades and rising pressure, and is found to relate particularly to the winds of January to March, inclusive.

Correlation coefficients resulting from a comparison of the winds of this period and the temperature (and pressure) after a lag of 3, 6, 9, 12 months, and annual, follow (table 2). There is here noted a fairly close minus relation, most marked for the fourth quarter and the year. A value of −0.51 for the concurring quarter (January to March) suggests a time lapse of less than three months, but is more likely a reflection of the fourth-quarter trades control. After a lag of 12 months however there is a marked falling off in the probability. The

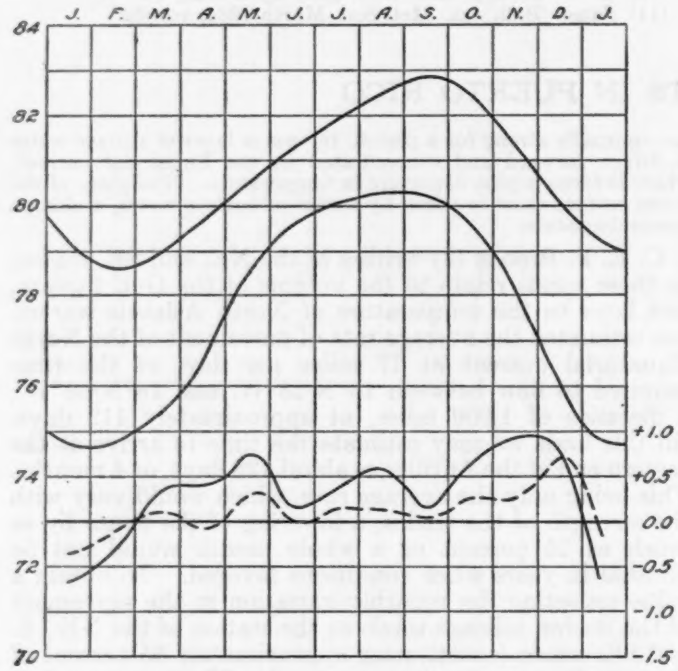

FIGURE 1.—Mean temperature curve of surface waters in Caribbean Sea (1) and air temperature at San Juan, P.R. (2) and deviations from the normal in 1930.

wind-pressure relation is expressed in a positive coefficient, somewhat smaller, but well-defined.

Variations in the temperature are not directly of great practical significance in Puerto Rico. The annual temperature of the Island varies between 70° and 80° F, with a deviation from the normal of seldom more than 3°. The rainfall variation, on the other hand, is most important to the agriculture of the section, owing to the high rate of evaporation and the consequent need for replenishment of moisture at frequent intervals. Only insofar as the temperature factor might be found to relate itself to the ensuing rainfall, is it thus of particular importance in long-range forecasts. Such relation, if existent, would also have an anterior trade-wind connection, based upon the latter's control of the temperature factor. As we find a certain positive correlation between the temperature of the late fall and winter months and the island rainfall, so too there occurs a negative though not so well defined relation between the January to March trades and the precipitation of the following year. The latter relation would take precedence in offering a six to nine months earlier indication. The temperature control, on the other hand, is found to yield somewhat more readily to correlation, and to further elaboration or limitation. Using the trade wind as a basis, however, there is shown an approximately 75 percent probability of the rainfall of the following year being of opposite departure sign. On this basis we may expect normal rains in the island in 1935, and the probability of a small deficiency in the current year, which latter has thus far been verified by the recent spring drought. In a quantitative correlation of the trades control, a coefficient of 0.48 is obtained with respect to the annual rainfall, or somewhat less than five times the probable error.

In using the temperature deviation as a basis, average departures at San Juan for the 5 months: October to February and for the 3 months: December to February were selected, the first or longer period average yielding slightly better values, both in the annual and seasonal relations, with the exception of the summer months. The 3 winter months give the same general relation, namely—a positive temperature deviation being followed by excess rainfall departures, and negative deviations by deficiencies, best indicated for the spring months and the annual period, with summer and autumn somewhat more variable (table 3). By eliminating all years of small-temperature deviations (below 0.5°), or conversely, including only the well-defined departures (of the winter period) there is a marked increase in the value of the indication, represented by a correlation coefficient of 0.78 in respect to the annual rainfall. There is thus a progressive relation, most consistent in years of well marked deviations, which may be expressed in terms of the approximate rainfall departure probable following certain temperature differences. Based upon the 35-year averages, a winter temperature deviation of 0.0° to 0.5° has been followed by an average departure in the annual rainfall of 1 inch or approximately normal; a deviation of 0.5° to 1.0° indicated a departure of approximately 5 inches or 8 percent, and any deviation of more than 1.0°, a departure in the annual rainfall amount by 9 inches, or 13 percent. Winter rains were omitted from the several correlations, except as a part of the annual. The rainfall at this season represents approximately 16 percent of the annual, being the least of the year. It also fails to yield any well-defined relation to preceding temperature values, one way or the other. A comparable instance of temperature-rainfall kinship is given by French (4) for Los Angeles and San Diego, California, where the temperature deviation for the month of March has indicated the following rainfall in 74 percent of the years of record at Los Angeles and 64 percent at San Diego. Relating the winter temperature deviation at San Juan and the Puerto Rico rainfall in like manner, a probability of 74 percent is obtained, or the same as at Los Angeles. Following a deviation of 0.5° or more, the probability is increased to 90 percent, or 15 years verification out of 17 years of record.

The cycle of the trades and ocean currents is an interesting one. Whether meteorological vagaries of abnormal years are caused by variations in the solar influence, it appears possible to trace certain types and persistencies more directly to the cycle of the trades. Thus we observe how a well-developed high pressure area in the North Atlantic initiates strong trade winds, which are followed by cooler ocean temperatures and currents that flow westward into the Gulf stream and eventually back to reinforce the area of Azores pressure for perhaps another cycle. And thus the weather of islands within the North Atlantic system of winds, including even parts of Europe may be determined to some extent, by conditions appar-

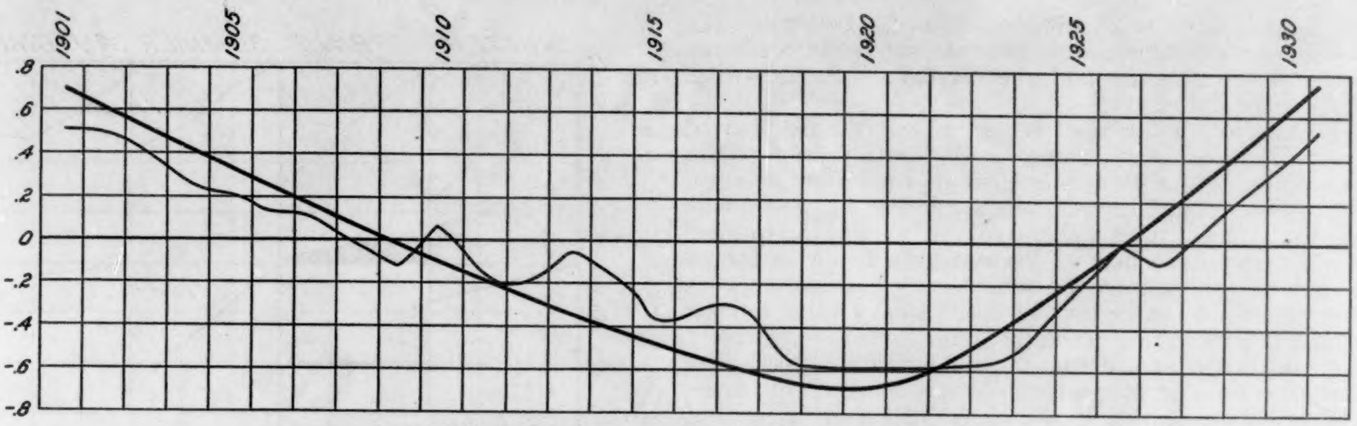

FIGURE 2.—Smoothed temperature departures, 1901, 1931, San Juan, P.R.

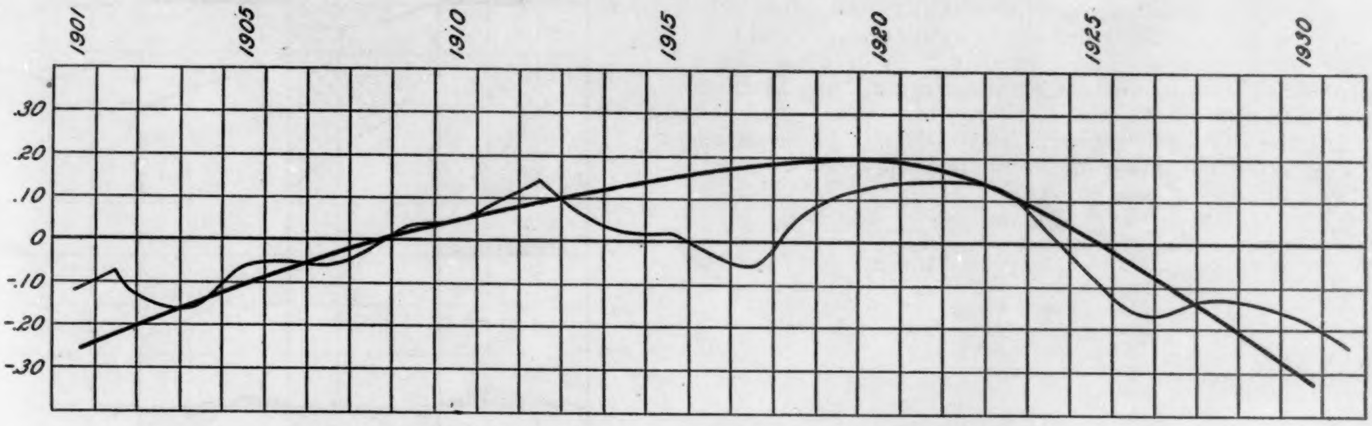

FIGURE 3.—Smoothed barometric departures (accumulated values) 1901-31, San Juan, P.R.

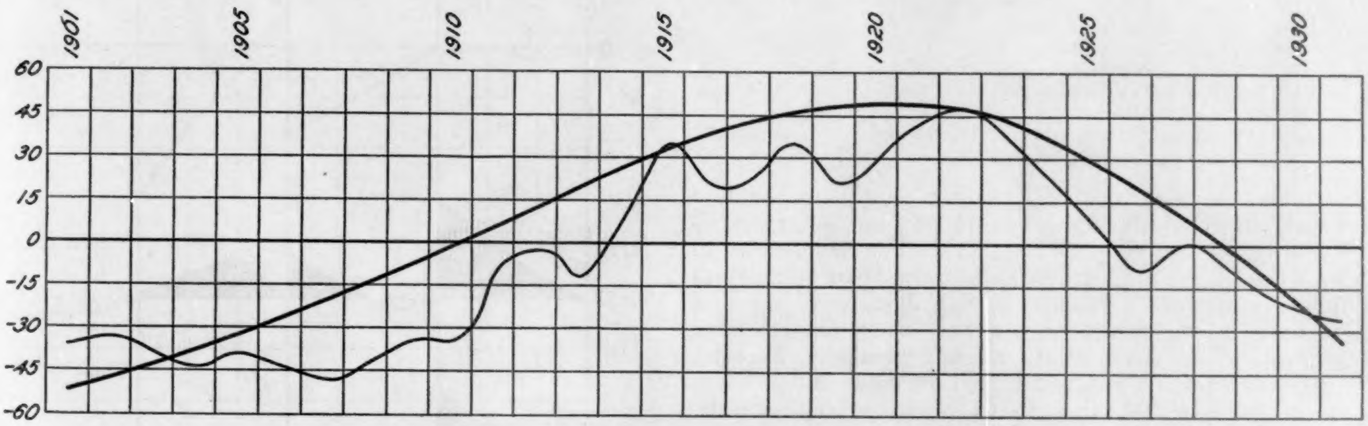

FIGURE 4.—Smoothed rainfall departures, 1901-31, Island of Puerto Rico.

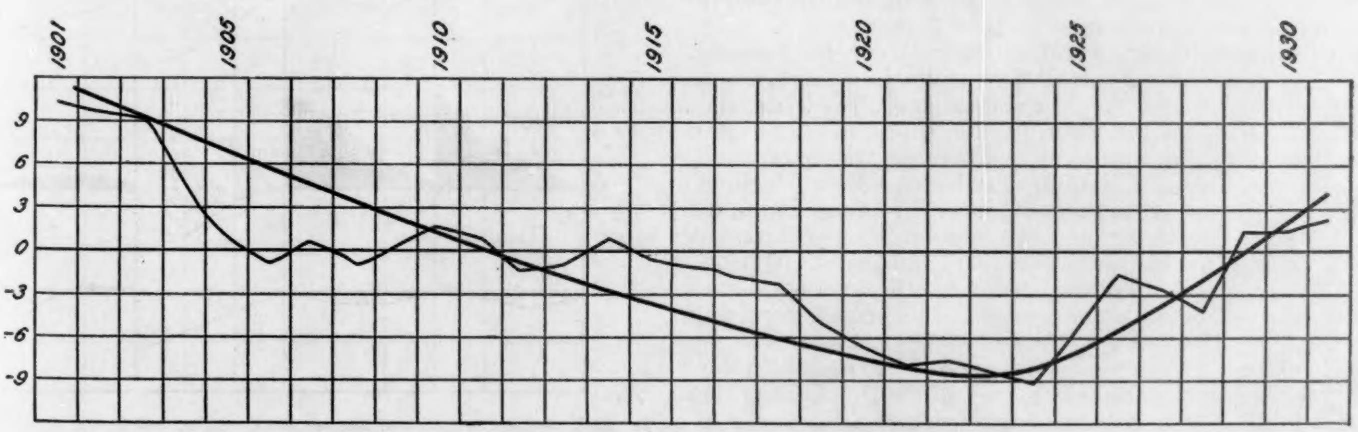

FIGURE 5.—Trade wind departures (smoothed) January to March, 1901-31, San Juan, P.R.

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ent as early as 18 to 24 months previous. Pettersson (1) instances a definite relation between the ocean temperatures of the Atlantic and the rainfall of the following year in Ireland.

In Puerto Rico rainfall is partly convectional, partly the result of equatorial rains (in the south portion of the island, particularly), during periods when the Atlantic high-pressure area has shifted position or become weakened. Tropical storms play a smaller part owing to their comparative infrequency. Except as a factor in forced ascent in the highlands, the influence of the trades appears more generally as an inverse one. Heavy rains for the Island as a whole, are generally accompanied by relatively low pressure, subnormal trades, and positive temperature, departures. The interrelation of pressure, temperature and rainfall is shown in the charts of smoothed annual averages, figures 2, 3, and 4. The trend of the trades over the same period of years shows that from 1900 to 1913 winds were in general below the normal, from 1914 to 1924 being excessive, and from 1925 to date becoming deficient. The movement during January to March is shown in figure 5.

In the 35-year period, 1899–1933, the following extremes of monthly and annual temperatures occurred, at San Juan:

MINIMUM

1904	August.
1907	January, February, March.
1910	September.
1913	May, June, annual.
1917	January, February, October, December.
1921	July.
1922	April, November.
1925	February.

MAXIMUM

1901	April.
1902	February.
1903	January, June.
1905	November.
1911	November.
1914	December.
1915	October.
1931	March, May, July, annual.
1932	August, September.

The cool weather of 1904, which was more or less general, occurred during a period of poor solar transmissibility, due to volcanic dust (5). The deficiencies in 1907 were likewise of wide extent. In 1910 subnormal temperatures were persistent at San Juan until the last 2 months of the year, having had their inception in November 1909. Cool weather also prevailed in Havana in 1910, and on the continent, in Louisiana and in New England, and in 1909 in such widely separated sections as Minnesota and Hawaii. In 1913 temperatures were relatively cool in the Eastern Caribbean, and the annual deviation was the greatest in the 35-year period. Conditions were similar to 1910, though more pronounced, and the cool weather extended to Cuba, Louisiana, and to northern latitudes, in Minnesota and New England. In 1917 temperatures were again subnormal and cool weather occurred westward to Havana, and over much of the continent: Colorado, Louisiana, New England. It was a year of great sunspot activity, the maximum for 35 years. Beginning in 1916 annual temperatures at San Juan were continuously below normal until 1925, a 10-year period. During that time the average deviation was −0.6, with the greatest deficiencies occurring in 1917–18–21–22–23. The years 1918–24 are used by Blair in his study of mild winters on the continent, referring particularly to the Missouri Valley (6). During this period the North Atlantic high-pressure area was con-

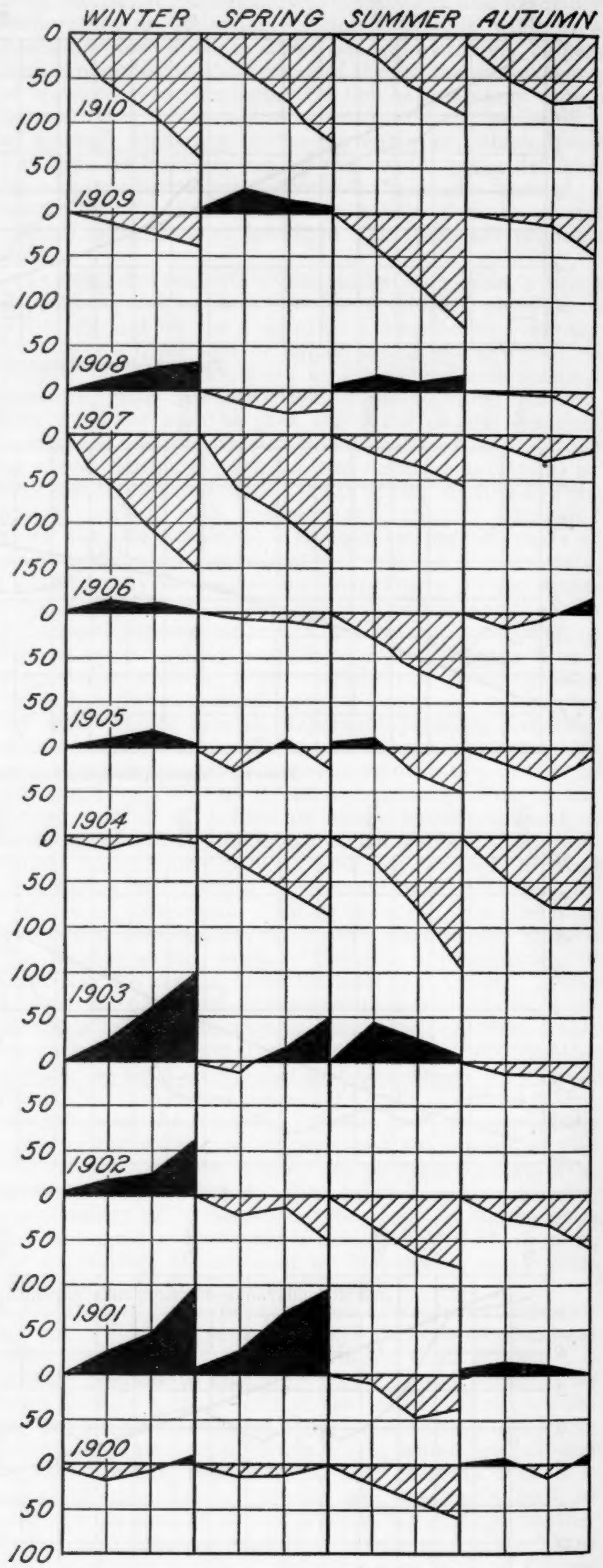

FIGURE 6.—Seasonal accumulated temperature departures, 1900–10, San Juan, P.R.

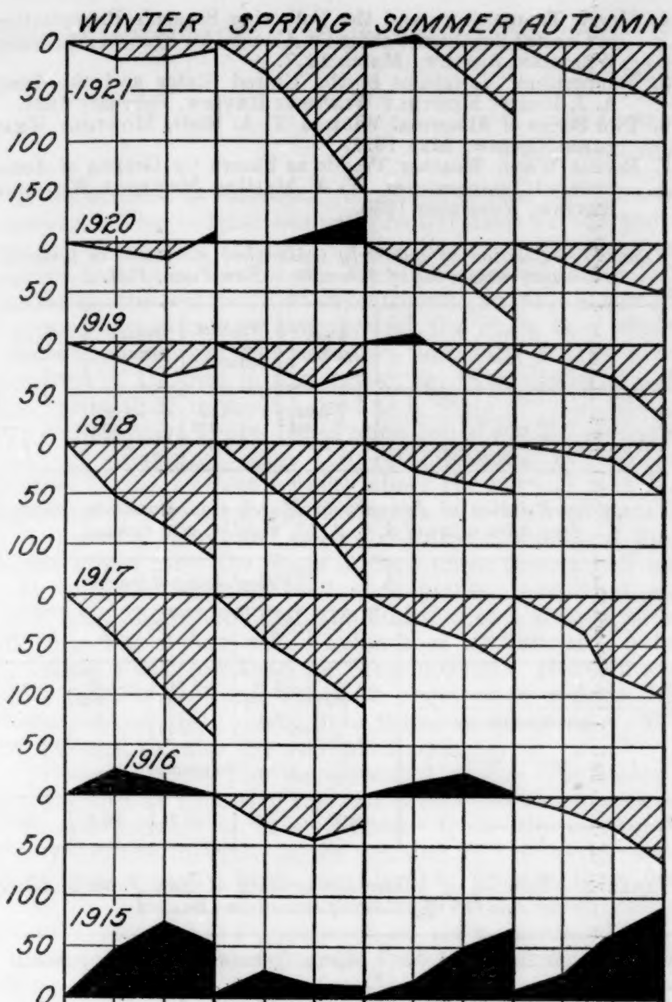

FIGURE 6.—Seasonal accumulated temperature departure, 1911–21, San Juan, P.R.

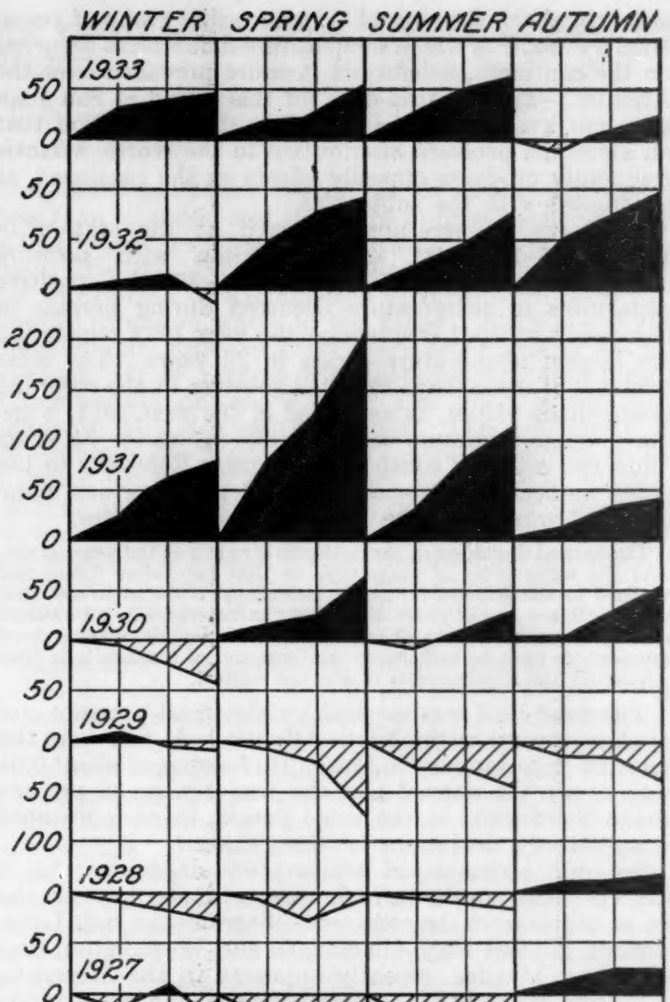

FIGURE 6.—Seasonal accumulated temperature departure, 1922–33, San Juan, P.R.

sistently above the normal. In an earlier group of years, cited by Blair, in which temperature deficiencies occurred on the continent, subnormal pressure prevailed over the Atlantic. Temperature data for this period at San Juan were not available. It is noted in this connection that an abnormal pressure distribution in the North Atlantic frequently produces opposite effects on the continent, as contrasted with the subtropics.

Excessive temperatures occurred at the station in 1901–2–3–5–15–31–32, in conjunction with pressure deficiencies. In 1901–03 and 1930–33 the positive departures in temperature occurred during periods of decreasing sunspot frequency—the year 1931 registering the largest temperature excess in 35 years. The solar influence is not always reflected however in the recorded temperature values, as exampled in the year 1913, when the extreme minimum annual temperature for 35 years coincided with the sunspot minimum. Referring to the years immediately preceding, 1910–11–12, which more nearly approximated the normal, Henry (**5**) states:

> The annual deviation of temperature for each of the years given, is of the same order of magnitude as that heretofore found and assigned to the sunspot influence, indicating, it seems to me, that in the ordinary run of years, those not characterized by an unusual number of areas or spots, the annual deviation of the mean annual temperature may be sufficiently uniform and of a magnitude that will satisfy the requirements of sunspot control.

The year 1913 was marked by abnormal pressure and wind movement in the North Atlantic. At San Juan the pressure from January to March 1913 averaged about 0.05 inch above the normal and the trades were 35 percent above the normal in the same period, in each instance being extreme deviations for the station.

Seasonal accumulated temperature departures for a series of years are shown in figure 6. Similar type graphs for six stations on the continent—Sacramento, Salt Lake, Denver, Kansas City, Cincinnati, and Washington, presented by Mattice, recently appeared in the MONTHLY WEATHER REVIEW (7). Comparison of the years 1920–1929, with the same period at San Juan, brings out the fact that what were mild years in the States (excepting 1920) were mostly subnormal in the Antilles. The winter trades were 10 percent above normal during the period.

LITERATURE CITED

1. A comparison of Hydrological and Meteorological Data, V. I. Pettersson, MONTHLY WEATHER REVIEW, November 1926.
2. Ocean Temperatures in Long-range Forecasting, C. F. Brooks, MONTHLY WEATHER REVIEW, November 1918.
3. C. E. P. Brooks on the effects of fluctuations of the Gulf Stream on Distribution of Pressure, abstract by A. J. Henry, MONTHLY WEATHER REVIEW, August 1927.
4. March Temperature and the Following Season's Precipitation in Coastal Southern California, George M. French, MONTHLY WEATHER REVIEW, March 1927.
5. Temperature Variations in the United States and elsewhere, A. J. Henry, MONTHLY WEATHER REVIEW, February 1921.
6. Two Series of Abnormal Winters, T. A. Blair, MONTHLY WEATHER REVIEW, May 1921.
7. Recent Warm Weather Trends as Shown by Graphs of Accumulated Temperatures, W. A. Mattice, MONTHLY WEATHER REVIEW, November 1930.

TABLE 1.—*Relation of quarterly trade-wind movement to temperature after a lag of 3 months. San Juan, P.R.*

	First quarter	Winds of second quarter	Third quarter	Fourth quarter
R	−0.62	−0.23	−0.29	−0.52
E	.104	.110	.107	.084
R/E	8.5	2.1	2.7	6.2

TABLE 2.—*Relation of January to March trade-winds to temperature after a lag of 3, 6, 9, 12, months, and annual*

	Following a lag of months				
	3	6	9	12	Annual
R	−0.62	−0.61	−0.74	−0.27	−0.73
E	.073	.074	.059	.130	.055
R/E	8.5	8.2	12.5	2.1	13.1
	To pressure				
R	+0.35	+0.37	+0.31	+0.37	+0.57

TABLE 3.—*Relation of winter temperature at San Juan to island rainfall of following season and annual*

	Spring	Summer	Autumn	Annual
R	+0.40	+0.33	+0.33	+0.55
E	.096	.103	.104	.082
R/E	4.26	3.20	3.08	6.71
	Temperature: October to February (5-month average) to rainfall of following season, and annual			
R	+0.54	+0.28	+0.39	+0.63
	Winter temperature deviation of 0.5 or more to rainfall of following season, and annual			
R	+0.56	+0.35	+0.45	+0.78

PRECIPITATION AVERAGES FOR THE STATE OF WASHINGTON, AS AFFECTED BY HABITABILITY

By LAWRENCE C. FISHER

[Weather Bureau Office, Seattle, Wash., July 1934]

Fluctuations in averages for State caused by extreme stations.—The normal annual precipitation at the individual measuring stations in the State of Washington ranges from 6 inches for the driest to approximately 150 inches for the wettest. Manifestly with so wide a spread between the extremes, averages for the State as a whole may show considerable variation according to the proportions of stations in the wetter, or drier, districts. If the value of 35 inches be used as a State normal, which is a conservative figure, based upon 190 of the 202 stations now in existence, then the establishment of 1 new station in the wettest region, where the normal may be 150 inches, will mean the inclusion of a station having 115 inches a year more than the State normal and this alone would raise the State normal more than a half an inch and the addition of 2 such places, more than an inch. On the other hand, the addition of a station with but 6 inches a year would mean that its normal is only 29 inches a year less than the State normal. Hence more than 6 such stations would be required to reduce the State normal by 1 inch, or 3 times as many as would be required to raise the normal an inch.

Present trends.—The development of the Climatological Service of necessity has not proceeded along such a balanced increase in new stations. Quite the contrary. For years the increase in the number of the wetter stations has actually been considerably greater than for those in the arid and semiarid regions. Consequently State averages have continued to show increased precipitation, notwithstanding the fact that during most of this period the State was in a cycle of decreasing precipitation, which reached a minimum in the years 1929 and 1930 as shown by stations in operation throughout the period.

Greatest cause of fluctuation: Habitability.—It is the object of this paper to discuss the variations in the distribution of observing stations from decade to decade and the principal cause thereof, that of habitability, using the term in its broadest meaning. No such admirable and even distribution of measuring stations has been possible as may be found in States that have more nearly homogenous lands, practically every acre of which is arable. In the more rugged and mountainous regions the problem has been to "Find the observer." Campaigns have been carried on in times past with that in view, while for a number of years the section center has been especially alert to secure observers in the unrepresented areas. There has been a great demand for information from the mountains and foothills in connection with water resources, which must supply cities and towns, irrigate the desert and semidesert lands, and furnish the motive power for hydroelectric development. The proportion of new stations in the foothills and mountains has been large in the past 25 years. There still remain areas of 300 to 400 square miles without a station. On the other hand, in some well-settled districts the interest in meteorological data has been so great that in some sections private and public agencies have provided their own equipment, and stations on a location map appear like telegraph poles along a right-of-way, they are relatively so close together. In the upper portion of the Yakima Valley from Ellensburg, elevation 1,510 feet, to the summit of the Cascades in Snoqualmie Pass, elevation 3,010 feet, are 6 measuring stations in an air-line distance of less than 52 miles, and the range in precipitation is from slightly over 9 inches to 91 inches. Some of these stations were established by the Weather Bureau and some by the Bureau of Reclamation at three large lakes that supply irrigation water to the valley. Each of the stations is quite different from every other and all are important. It so happens that there are now four official observing stations in Seattle. The oldest is the main office in the downtown district. The University of Washington has maintained a cooperative station on the campus for many years. More recently the Weather Bureau established the Airport Station at Boeing Field in the extreme southern part of the city, while the naval air station was located a short distance beyond the city limits to the northeast. The four stretch out some 15 miles and are spaced about 5 miles apart.

Sparsely inhabited regions.—The conspicuous areas without observers have been, and still are, in the mountains, the arid regions, and in the remote forests. The mountains have been forbidding as a place of permanent dwelling because of their inaccessibility and ruggedness, because of dense timber that must be penetrated to reach them, and because of the very deep snows of the winter-half of the year. The arid regions have failed to properly support life. But habitability is relative. The railroads crossed the States from east to west and station agents became weather observers in the driest places and in mountain passes. At the summits or at the entrances to tunnels, the railroads must continually have stations in order to maintain clear tracks and to operate trains over steep grades. Irrigation has changed some barren, sagebrush, jack rabbit, and coyote valleys into the most desirable places for intensive horticultural and agricultural pursuits and has multiplied opportunities for obtaining observers far beyond any reasonable need. An occasional mine has been an observing point, but as a rule, the records may be kept faithfully for a few years and then perhaps the mine be abandoned. Some very good mining stations are now functioning. With the development of irrigation there also has been a material increase in the number of stations at reservoirs and lakes in the mountains and foothills where it has been necessary to maintain a keeper. Hydroelectric companies and municipalities have pursued a similar course, notable among which are the Puget Sound Power & Light Co. and the cities of Seattle, Tacoma, Walla Walla, Everett, Aberdeen, Hoquiam, and others. In recent years the establishment of mountain resorts has contributed to the number of the more elevated stations. The Rainier National Park, embracing 100 square miles, has three cooperating stations, and there are others in the national forest surrounding the park. Mount Baker has one. The Portland Y.M.C.A. has a permanent establishment on the shores of Spirit Lake on the northerly slopes of Mount St. Helens. When the Milwaukee Railroad built its tunnel through the Cascades it abandoned the station in Snoqualmie Pass, but later an inn was erected on the highway by private enterprise, which was operated at first only when the snow was gone. Now the State highway department maintains an open road throughout the winter despite the deep snows, and the weather records are continuous, in fact an airways observing station is now maintained there. Since skiing

has become popular, many of the winter resorts are open in winter as well as in summer, and records are likewise continuous. The State highway department plans to keep open other passes through the Cascades as funds become available. The forested areas, especially the national forests, have contributed a number of new stations. Many of these were established in connection with the fire-weather work of the Bureau. National and State forestry services and private agencies interested in logging operations have cooperated in observing precipitation and humidity.

The foregoing development has made it possible for one or more persons to dwell in the inhospitable places, and some of the valleys have become well populated by reason of irrigation, yet the rugged mountains as a whole are still unable to attract, retain, or support permanent residents. The term habitability has been used in a very relative sense.

Normal precipitation.—In practice the normal precipitation for a State is an average of the normals for a number of places as uniformly distributed over the entire area as possible. A normal precipitation weighted according to density of population would seem rather absurd, and yet to a certain extent this has actually resulted in Washington, and without doubt, in most of the other mountainous States. Insofar as such a normal represents the precipitation where the masses now live and will continue to live in large numbers, it serves a valuable purpose. At least, such an average is more useful to the majority of citizens. The seeker for reliable information should always consult the normals for individual stations. There is no substitute that will suffice. In a Seattle second-hand book store is a meteorological atlas for the United States which was published in the early nineties. Within it are portrayed many climatic charts. All of northwestern Washington is indicated to have more than 60 inches of precipitation annually. The author's chart was prepared using only two stations in that section; Neah Bay, which has an annual rainfall of more than 100 inches, and Olympia which has 52 inches. Port Townsend had a record at that time. It was formerly Fort Townsend, centrally located within that region. Its normal is less than 20 inches, while Sequim, which is also in the lee of the Olympic Mountains, has averaged less than 17 inches, and irrigation is practiced there.

Opposite trends.—In the distribution of new stations in the State, there are two somewhat opposing trends as to whether the State normal shall increase or decrease. The one is the location of stations where people may flock and the other the location of measuring stations with a view to further determining the water resources in the mountains. On the whole, the former will probably tend to reduce the normal and the latter to increase it. When the Grand Coulee Dam project is finally completed, more than a million acres of either totally unproductive or partially productive land will come under intensive cultivation, and will support a considerable horticultural and agricultural population, and will make possible observing stations in a now poorly represented dry region. Other development will make possible communities and observing points where representation is inadequate. Most of these are apt to be either dry or moderate in precipitation. The amount of precipitation a region may have is, as a rule, not the determining factor in the density of population. The most populous region of the State is the east shore of Puget Sound where the transcontinental railroads first reached tidewater, and a great and deep inland harbor was available for cheaper vessel transportation. The cities of Seattle and Tacoma are the nearest points to the passes in the Cascades used by the railroads, and in this region also was a wealth in lumber and fish. Here people naturally congregated and the results probably would not have been greatly different had Seattle's normal precipitation of 34 inches and Tacoma's 40 inches been double, as is the case on Grays and Willapa Harbors. The latter places are prosperous regions with small cities, whose principal handicap has been that railroads must travel more than 100 miles farther to reach tidewater. The demand for more data from the mountains is constant since their heavy rains and snows afford millions of potential horsepower as the water cascades to form the larger streams and moves in a mighty volume to the sea and the rains and snows nurture billions of feet of timber. No doubt the increase in stations in these wetter districts will more than offset the influence of new stations in drier sections.

Quadrangles to equalize the distribution of stations.—Since the distribution of stations was so uneven, Summers divided the State into 15 so-called quadrangles, all of approximately equal areas and the terrain and other conditions as nearly homogenous as it was possible to attain. This system was put into effect in 1927 and is now in use in computing both temperature and precipitation monthly and annual averages. It affords a fairer distribution on a somewhat more nearly geographical basis. Figuratively, Seattle gets four votes in its quadrangle average but the quadrangle represents only one-fifteenth of the State average.

Table 1.—*Normals of precipitation for Washington computed from present day normals for individual stations in operation at the end of successive decades. Straight averages except as indicated*

Year	Number of stations			Normals		
	West	East	State	West	East	State
1890	16	4	20	47.82	13.48	40.96
1900	33	35	68	56.42	14.10	34.64
1910	39	57	96	56.78	15.81	32.46
1920	58	82	140	55.50	16.20	32.48
1930	88	102	190	63.42	16.56	38.24
	By quadrangle method					
1930	88	102	190	59.95	22.84	35.21

Distribution of stations at the end of each decade and the corresponding averages (see table I).—State averages for the various months and years have been prepared and are now in use for each year as far back as 1890, when apparently only twenty stations were in operation. Of these, 16 were in western Washington and only 4 in the eastern part of the State or in the ratio of 4 to 1. By "western Washington" is meant all that section of the State west of the summit of the Cascade Range, and "eastern Washington" is all that to the east. The ratio of the two areas is approximately 1 to 2. Thus it will be seen that in 1890 there was a great distortion in the averages for the State due to this distribution, since the smaller division had four times as many stations as the larger. Using present-day normals for each of these 20 stations, their average makes 41 inches for the normal for the State, an amount greater than obtained from any other computations. Yet the normals for each division are less than ever subsequently obtained. The reason for the larger number of stations in western Washington at that time is that there was more activity in that part of the State. Only one of the stations west

of the Cascades was not on a body of water reached by ocean vessels, and that one, Chehalis, lies in a wide fertile valley about midway between Puget Sound and the Columbia River. None of the 16 was even in the foothills. The wettest stations were in the extreme northwest, and were at Tatoosh Island, Neah Bay, and La Push. The average for western Washington was 47.82 inches, while that for the four stations in the eastern division was 13.48 inches. The 2,000 miles of shoreline, including that part of the Columbia River touching Washington west of the Cascades, the ocean coast including Willapa and Grays harbors, the Straits of Juan De Fuca and Puget Sound with its many ramifications and islands offered ready and inviting sites for habitation. By 1900 the situation as regards distribution of stations was better, with 33 in the west and 35 in the east, or a total of 68, yet the west still had an undue proportion so far as geographical distribution was concerned. A straight average of present day normals for the 68 stations gives the State a normal of 34.68 inches or more than six inches less than the 1890 figures, and this, notwithstanding the fact that the normal for western Washington rose to 56.42 inches due to the addition of a number of very wet places including two in the mountains. The average for the east becomes 14.10 inches or nearly an inch more than the average of the four 1890 stations. The 10 years ending with 1900 has proved to be actually the wettest decade of the four decades under consideration. The reduction in the normal is due to the change in the relative proportion of stations in the east and west divisions of the State.

In 1910 the number of stations in the west had risen to 39 while in the east the number shows a greater increase to 57. The west continued, however, to have more than its proportion according to area ratio of 1 to 2. A straight average of the 96 station values makes a State normal of 32.46 inches or nearly two inches less than the 1900 normal and 8½ inches less than the 1890 normal. For the west the normal increased slightly while for the east it rose to 15.81 inches or 1.71 inches more than it was for 1900. Here we find that the average for each division taken separately shows an increase, yet that for the State shows a decrease again due to the change in the proportionate distribution. The reason for the increase in the normal for the eastern division was that in 1909 began a campaign to secure more precipitation measuring stations in the mountains and also to the fact that gages were placed at forest ranger stations.

In 1920 the total number of stations had increased to 140; 58 in the west and 82 in the east. In this case the west increased more than the east, further distorting the proportion. However, the State average rose only 0.02 inch. The normal for the west decreased to 55.50 inches or 1.28 inches less than in 1910, while in the east the average rose 0.39 inch to 16.20 inches. There was a notable increase in stations in the mountain regions of eastern Washington, especially in the Yakima drainage basin, where the great irrigation project was being further developed, while in the west there were new stations in the drier portions and also some in the wetter.

In 1930 the number of stations had risen to 202; however some 12 of these have such short records that no attempt was made to include normals for them. Of the 190 stations used, 88 were in the west and 102 in the east, the west having far too many to balance the 1:2 area ratio. There was a 50 percent increase in stations in the west and only a 25 percent increase in the east. Two-thirds of the new stations west of the Cascades summit were in the wetter mountain or forested regions, while a smaller proportion of those east were thus located. Using a straight average, as was done in the preceding computations, the State normal rises to 38.24 inches, or nearly 6 inches at the very time when individual stations over the State were showing the driest decade, which include the record breaking years of 1929 and 1930. Had the new stations been similar to the old, and if the proportion of stations had remained undisturbed the normal would have shown a decrease instead of a marked increase. For western Washington the straight average exceeds 63 inches and for the east 16.56 inches. It is quite apparent that with so large a proportion of the stations in the wettest sections of the State the average obtained is not fairly representative if equal areas are to be considered. If all the stations are distributed to their respective quadrangles and each quadrangle averaged separately and then the 15 quadrangle averages combined, the normal for the State becomes 35.21 inches; 59.95 for the west and 22.84 for the east. This allocation of stations lowers the average for the western division but increases it for the eastern. It so happens that the average thus obtained for the State, of 35.21 inches, is only a small amount greater than the period average of the yearly averages for the State.

Summers, after exhaustive computations extending averages back much farther and estimating normals for all the new stations, found that distributed by quadrangles the State normal is about 39 inches.

Precipitation on ridges and peaks not evaluated.—Another phase of habitability is that a large proportion of stations are in the valleys or the lower places, for the railroads and highways seek the easier grades and in the valleys are apt to be the most fertile fields. It has been shown that the most populous places west of the Cascades are at or near sea level and even in eastern Washington on the plateau the towns are in the coulees for the most part and many a rancher avoids the stronger winds of the ridges. Comparatively little is known of the precipitation on the ridges, hilltops, and mountain peaks. A state normal to be truly representative on a geographical basis might have to show a measuring station for every square mile, so great are the variations, and such a normal would need to include the summits of Mounts Rainier, Adams, Baker, Glacier, and Saint Helens with their eternal snows and glaciers. Such an eventuality seems rather incredible. Yet one advertising enthusiast has already sought to establish a winter residence and radio station on the summit of Mount Rainier and wishes meteorological equipment. A normal so representative as outlined seems about as remote as infinity, yet as time passes no doubt more observing points will be placed in sections now unrepresented.

Whatever value for the normal precipitation for the State a Section Center may use, it should bear a close relation to the stations that are active, otherwise a monthly State average may be greater than the normal, while the great majority, or even all of the individual stations may show a deficiency.

UPPER-AIR WINDS OVER NORTHERN ALASKA DURING THE INTERNATIONAL POLAR YEAR, AUGUST 1932–AUGUST 1933, INCLUSIVE

By Loyd A. Stevens

[Weather Bureau, Washington, D.C., July 1934]

The United States Weather Bureau has prepared some 25,000 pilot-balloon summary forms for the International Polar Year Commission, on which are entered the data from all Weather Bureau pilot-balloon stations, including 1 in Puerto Rico and 4 in Alaska for the period, August 1932 to August 1933, inclusive. Since the International Commission was especially interested in observations in and near the polar regions, the Weather Bureau established, and maintained for the greater portion of the Polar Year, a special station at Point Barrow, the northernmost point of land in Alaska; latitude 71°23′ N., longitude 150°17′ W. Along with other important matters, pilot-balloon observations were taken twice daily, weather permitting, from September 14, 1932, to August 11, 1933, inclusive. During this period 580 flights were made; or 88 percent of the total scheduled. Of these, 473 reached 1,000 meters; 276, 3,000 meters; 108, 5,000 meters; and 15, 10,000 meters. The highest single flight was made on July 9, 1933, when an altitude of 12,500 meters was attained, at which level the wind was NNE., 15 meters per second. The highest velocity recorded during the entire period was 41 meters per second from the west on October 7, 1932, at an altitude of 10,350 meters.

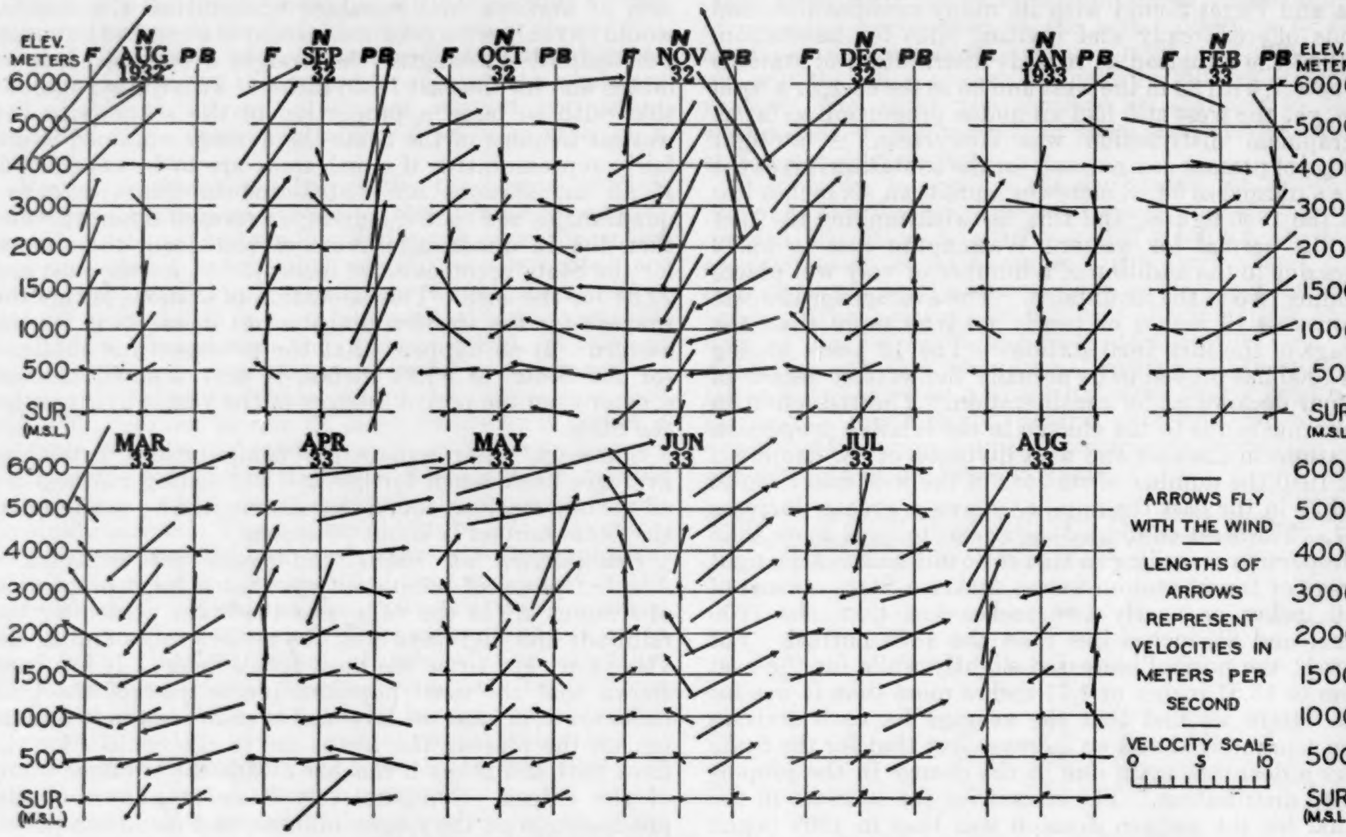

Figure 1.—Resultant winds at Fairbanks, Nome, and Point Barrow, Alaska

RESULTANT WINDS

Since resultant winds, based upon a sufficient number of observations, indicate the true mass movement of the atmosphere, they are shown here in some detail for the three stations, Point Barrow, Nome, and Fairbanks; being given for all standard levels by months and for the year. The monthly resultants are shown for levels up to 6 kilometers insofar as data are available, and the annual values are given for the two additional levels of 7 and 8 kilometers. In some cases the number of observations for an individual month was small, causing apparent inconsistencies and irregularities, but in general the air movement over this area is believed to be indicated quite accurately in figures 1 and 2 on which the resultants have been drawn.

Easterly winds predominate below three kilometers at all three stations during the greater portion of the year. This may be attributed to the influence of the Aleutian Low, the dominant pressure area in that region, usually centered to the west or southwest of Alaska. During mid-summer however, the Aleutian Low is rather weak and a stronger area of high pressure builds up over the north Pacific. The effect of this pressure distribution is reflected in the westerly resultants which prevail during June, July, and August. Above 3 kilometers the resultants are in general from the west.

It will be noted that the shift from easterly to westerly resultant directions occurs between 2 and 3 kilometers at Point Barrow and Fairbanks, and between 5 and 6 kilometers at Nome. This is probably due to the fact that the center of the Aleutian Low is on the average nearer to Nome than to the other two points.

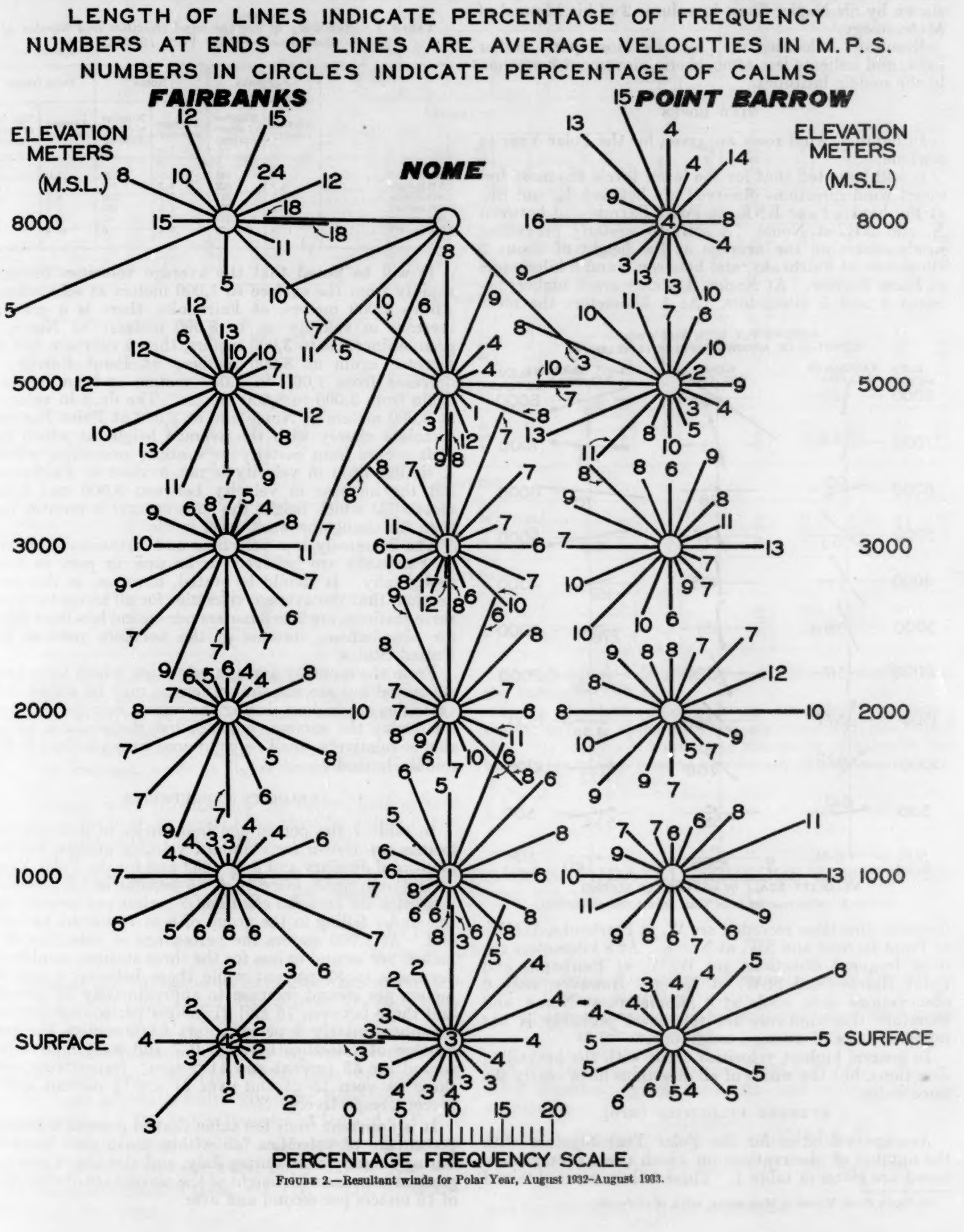

FIGURE 2.—Resultant winds for Polar Year, August 1932–August 1933.

The resultant wind directions compare favorably with the average pressure maps for the North Polar regions shown by Sir Napier Shaw in volume 2 of his Manual of Meteorology.[1]

Resultant velocities are, for the most part, rather light, and indicate less atmospheric movement here than in the middle latitudes.

WIND ROSES

In figure 3, wind roses are given for the Polar Year as a whole.

It will be noted that for the lower levels the most frequent wind directions observed are between E. and SE. at Fairbanks, E. or ENE. at Point Barrow and between N. and NE. at Nome. A shift to westerly prevailing winds occurs on the average at the height of about 2 kilometers at Fairbanks, and between 2 and 3 kilometers at Point Barrow. At Nome, it occurs much higher, between 4 and 5 kilometers. At 5 kilometers the most frequent directions recorded are W. at Fairbanks, WNW. at Point Barrow and SW. at Nome. At 8 kilometers the most frequent directions are WSW. at Fairbanks and Point Barrow and SSW. at Nome. However, only 6 observations were made at 8 kilometers at Nome, and therefore the wind rose for this level probably is not representative of average conditions.

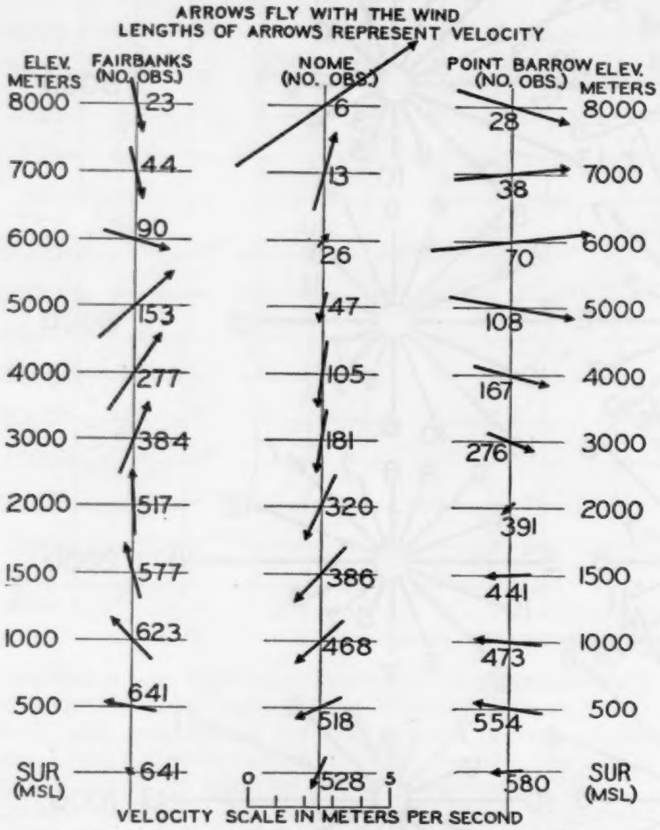

FIGURE 3.—Wind roses for Polar Year, August 1932–August 1933.

In general highest velocities occur with the prevailing directions, but the winds of all directions have nearly the same value.

AVERAGE VELOCITIES (MPS)

Average velocities for the Polar Year together with the number of observations on which these averages are based are given in table 1. These values were obtained by dividing the sum of all velocities by the total number of observations.

TABLE 1.—*Summary of average wind velocities and number of observations—Polar Year, 1932–33*

	Fairbanks		Nome		Point Barrow	
	Average velocity	Number of observations	Average velocity	Number of observations	Average velocity	Number of observations
Surface	1.5	641	3.5	528	5.0	580
1,000 meters	6.2	623	6.3	468	9.2	473
2,000 meters	7.3	517	7.7	320	8.8	391
3,000 meters	7.9	384	7.9	181	8.7	276
5,000 meters	11.1	153	7.3	47	9.1	108
8,000 meters	12.8	23	9.3	6	10.4	28

It will be noted that the average velocities increase rapidly from the surface to 1,000 meters at all stations. Above 1,000 meters, at Fairbanks, there is a gradual increase in velocity up to 8,000 meters; at Nome, a gradual increase to 3,000 meters, then a decrease and an increase again at 8,000 meters; at Point Barrow, a decrease from 1,000 to 3,000 meters and an increase again from 3,000 to 8,000 meters. The drop in velocity at 5,000 meters at Nome and at 3,000 at Point Barrow, coincides closely with the average height at which the shift occurs from easterly to westerly prevailing winds. A similar drop in velocity is not evident at Fairbanks, but the increase in velocity between 2,000 and 3,000 meters (at which height the shift occurs) is notably less than the change between other levels.

The extremely low velocities and frequency of calms at Fairbanks are believed to be due in part to local topography. It should be stated, however, in this connection, that the average velocities for all levels for these three stations, are 2 to 3 meters per second less than those for pilot-balloon stations in the northern part of the United States.

From the monthly average velocities, which have been computed but are not shown here, it may be stated that velocities are highest during the winter months and lowest during the summer months, but the seasonal variation is relatively small as compared with stations in the middle latitudes.

VELOCITY FREQUENCIES

In table 2 the percentage frequencies of different velocities are shown for standard velocity groups, for the months of January and July 1933 and for the Polar Year.

At the surface, more than 85 percent of all recorded velocities are between calm and 7 meters per second; the remainder falling in the group of 8 to 14 meters per second. At 1,000 meters the percentage of velocities of 7 meters per second or less for the three stations combined, decreases to 52 percent while those between 8 and 14 meters per second increase to approximately 32 percent and those between 15 and 21 meters per second amount to approximately 6 percent. At 5,000 meters the percentage of velocities between 0–7 and 8–14 meters per second are 45 percent and 41 percent, respectively, and those between 15–21 and over 21 are 11 percent and 3 percent, respectively.

It is apparent from the table that in general a greater percentage of velocities fall within the higher brackets during January than during July, and also that there is a gradual increase with height of the percentage of velocities of 15 meters per second and over.

[1] Sir Napier Shaw, Manual of Meteorology, vol. 2, pp. 216 to 266.

TABLE 2.—*Percentage frequency of velocities (meters per second) in different velocity groups. Highest percentage underscored*

Velocities in—	January						July						Year					
	0-1	2-7	8-14	15-21	>21	Number of observations	0-1	2-7	8-14	15-21	>21	Number of observations	0-1	2-7	8-14	15-21	>21	Number of observations
SURFACE																		
Fairbanks	93	7				45	41	51	8			49	64	34	2			641
Nome	21	64	15			43	24	73	3			37	21	66	12	1		528
Point Barrow	5	93	2			60	6	81	13			63	3	86	10	1		580
1,000 METERS																		
Fairbanks		64	32	4		44	7	72	21			47	5	66	27	2		623
Nome		59	41			39	13	53	27	7		30	5	62	27	4	2	468
Point Barrow	2	51	33	7	7	57	2	42	39	15	2	54	2	40	43	11	4	473
2,000 METERS																		
Fairbanks	3	55	36	6		33	8	65	22	5		40	7	55	31	6	1	517
Nome	7	38	41	14		29	5	58	26	11		19	2	48	42	8		320
Point Barrow		51	33	16		57	2	51	35	12		43	1	46	36	15	2	391
3,000 METERS																		
Fairbanks	6	50	33	11		18	4	60	36			28	2	51	37	7	3	384
Nome		22	55	17	6	18	8	46	38		8	13	2	49	42	5	2	181
Point Barrow	2	46	35	15	2	46	3	46	42	9		33	2	46	38	13	1	276
5,000 METERS																		
Fairbanks		33	67			3		50	50			6	3	34	42	15	6	153
Nome			100			2		40	60			5	9	45	40	4	2	47
Point Barrow	7	54	31	8		13	13	67	20			15	4	40	42	13	1	108
8,000 METERS																		
Fairbanks						0						0		36	36	5	23	23
Nome						0						0		33	50	17		6
Point Barrow						0		30	60	10		10	7	21	47	25		28

In summary the following facts stand out:

1. The mass movement of air in the region of Northern Alaska is relatively small as compared with that for the northern part of the United States.
2. Below 3,000 meters, on the average, easterly winds are most frequent, while at higher levels westerly winds prevail.
3. Average wind velocities for this region, both surface and aloft, are 30 to 40 percent less than for points in the northern part of the United States.
4. Individual velocities do not deviate greatly from the average.

Since Northern Alaska is an heretofore uncharted region, as far as upper air winds are concerned, it is hoped that this study will contribute something of value to our knowledge of the general circulation of the atmosphere.

TABLES (IN MILLIBARS) OF THE "PRESSURE OF SATURATED AQUEOUS VAPOR OVER WATER" AT TEMPERATURES FROM 0° TO −50° C.

By LOUIS P. HARRISON
[Weather Bureau, Washington, D.C.]

Tables of the "Pressure of Saturated Aqueous Vapor over Water" at temperatures below 0° C. are frequently required in aerological work, particularly in connection with the interpretation of hair-hygrograph readings. Tables of this nature down to −50° C. have been prepared on the basis of relationships given by Washburn in an article entitled "The Vapor Pressure of Ice and of Water Below the Freezing Point" (MONTHLY WEATHER REVIEW, vol. 52, October 1924, pp. 488–490. See also International Critical Tables, vol. III, p. 210, McGraw-Hill Book Co., 1928).

If e_i = pressure of saturated aqueous vapor over ice at temperature t.

e_w = pressure of saturated aqueous vapor over water at temperature t.

t = temperature in °C.

and T = absolute temperature $= (273.1+t)°K.$,

then Washburn gives for e_i (in mm of mercury) the expression

$$\log_{10}e_i = \frac{-2445.5646}{T} + 8.2312 \log_{10}T - 0.01677006\,T + 1.20514\times10^{-5}.T^2 - 6.757169 \qquad (1)$$

and for the ratio $\left(\frac{e_w}{e_i}\right)$, the expression

$$\text{(2)}\quad \log_{10}\left(\frac{e_w}{e_i}\right)=\frac{-1.1489t}{(273.1+t)}-1.330\times10^{-5}t^2+9.084\times10^{-8}t^3-1.08\times10^{-9}t^4$$

We can compute values of e_w for various temperatures by making use of the equation

$$\text{(3)}\qquad e_w=e_i\left(\frac{e_w}{e_i}\right),$$

where values of e_i are obtained by means of equation 1 and values of $\left(\frac{e_w}{e_i}\right)$ are obtained by means of equation 2.

Washburn has already given a table of values of e_i for every tenth degree over the range 0° to −30° C. For the present work, values of e_i (in mm of mercury) were computed by means of equation (1) for every whole degree over the range −30° to −50° C.; and values for every intermediate half degree were obtained from these by the use of Newton's interpolation formula. The computations were carried out to five significant figures. Values of e_i for every tenth degree were obtained by linear interpolation between each half degree of temperature over the range in question. All the values over the range 0° to −50° C. were converted to millibar units through multiplication by the factor 1.333224. The final table which was thus obtained is not reproduced here.

Values of $\left(\frac{e_w}{e_i}\right)$ were computed by means of equation (2) for every whole degree over the range 0° to −50° C.; and values for every tenth degree were obtained by linear interpolation. Table 1 contains the results of the former computations.

Table 2 shows the values of e_w obtained by multiplying the values of e_i (in mb), referred to above, by the ratios $\left(\frac{e_w}{e_i}\right)$ for the corresponding temperatures.

These are mostly given to four significant figures; however the fourth figure, and in the lower part of the table the third, cannot be regarded as strictly accurate, owing to uncertainties in the equations and to slight uncertainties arising from the dropping of following significant figures during the course of the numerous arithmetical operations.

Acknowledgment is due to Messrs. C. Russo and A. D. Hustead of the Aerological Division of the Weather Bureau, for carrying out the laborious computations required in the preparation of the tables and for the care they exercised throughout that performance.

TABLE 1.—$\left(\frac{e_w}{e_i}\right)$, *ratio of the pressure of saturated aqueous vapor over water to the pressure of saturated aqueous vapor over ice*

t	0	1	2	3	4	5	6	7	8	9
°C.										
−0	1.0000	1.0097	1.0196	1.0295	1.0396	1.0497	1.0600	1.0704	1.0809	1.0914
−10	1.1021	1.1129	1.1238	1.1349	1.1460	1.1572	1.1686	1.1800	1.1916	1.2032
−20	1.2150	1.2268	1.2388	1.2509	1.2630	1.2753	1.2877	1.3001	1.3127	1.3253
−30	1.3381	1.3509	1.3638	1.3768	1.3899	1.4031	1.4163	1.4296	1.4430	1.4564
−40	1.4699	1.4835	1.4971	1.5108	1.5245	1.5382	1.5520	1.5658	1.5797	1.5935
−50	1.6074									

TABLE 2.—*Pressure of saturated aqueous vapor over water (millibars)*

t	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
° C.										
−0	6.105	6.061	6.017	5.974	5.931	5.888	5.845	5.803	5.761	5.719
−1	5.677	5.635	5.594	5.553	5.513	5.473	5.433	5.393	5.353	5.314
−2	5.275	5.236	5.198	5.160	5.122	5.084	5.046	5.009	4.972	4.935
−3	4.898	4.862	4.826	4.790	4.754	4.719	4.684	4.649	4.614	4.580
−4	4.546	4.512	4.478	4.445	4.412	4.379	4.346	4.313	4.281	4.249
−5	4.217	4.185	4.153	4.122	4.091	4.060	4.029	3.999	3.969	3.939
−6	3.909	3.879	3.849	3.820	3.791	3.762	3.733	3.704	3.676	3.648
−7	3.620	3.592	3.564	3.537	3.510	3.483	3.456	3.430	3.404	3.378
−8	3.352	3.326	3.300	3.274	3.249	3.224	3.199	3.174	3.149	3.124
−9	3.100	3.076	3.052	3.028	3.004	2.981	2.958	2.935	2.912	2.889
−10	2.866	2.844	2.821	2.799	2.777	2.755	2.733	2.711	2.690	2.669
−11	2.648	2.627	2.606	2.585	2.564	2.544	2.524	2.504	2.484	2.464
−12	2.444	2.424	2.405	2.386	2.367	2.348	2.329	2.310	2.291	2.273
−13	2.255	2.237	2.219	2.201	2.183	2.165	2.147	2.130	2.113	2.096
−14	2.079	2.062	2.045	2.028	2.011	1.995	1.979	1.963	1.947	1.931
−15	1.915	1.899	1.883	1.868	1.853	1.838	1.823	1.808	1.793	1.778
−16	1.763	1.748	1.734	1.720	1.706	1.692	1.678	1.664	1.650	1.636
−17	1.622	1.608	1.594	1.581	1.568	1.555	1.542	1.529	1.516	1.503
−18	1.490	1.477	1.465	1.453	1.441	1.429	1.417	1.405	1.393	1.381
−19	1.370	1.358	1.346	1.335	1.324	1.312	1.301	1.290	1.279	1.268
−20	1.257	1.246	1.235	1.224	1.214	1.204	1.194	1.184	1.174	1.164
−21	1.153	1.143	1.133	1.123	1.113	1.103	1.093	1.083	1.074	1.065
−22	1.056	1.047	1.038	1.029	1.020	1.011	1.002	.993	.985	.976
−23	.967	.958	.949	.941	.933	.925	.917	.909	.901	.893
−24	.885	.877	.869	.861	.854	.846	.838	.830	.823	.816
−25	.809	.802	.795	.788	.781	.774	.767	.760	.753	.746
−26	.739	.732	.726	.720	.713	.706	.699	.693	.687	.681
−27	.674	.668	.662	.656	.650	.644	.638	.632	.627	.621
−28	.615	.609	.603	.598	.592	.587	.581	.576	.571	.565
−29	.560	.554	.549	.544	.539	.534	.529	.524	.520	.515
−30	.510	.505	.501	.496	.491	.486	.482	.477	.473	.468
−31	.464	.460	.455	.451	.447	.442	.438	.434	.430	.426
−32	.421	.418	.414	.410	.406	.402	.398	[illegible]	.390	.386
−33	.383	.379	.375	.372	.368	.364	.361	.357	.354	.350
−34	.347	.344	.340	.337	.334	.330	.327	.324	.321	.318
−35	.314	.311	.308	.305	.302	.299	.296	.293	.290	.288
−36	.285	.282	.279	.276	.273	.271	.268	.265	.263	.260
−37	.257	.255	.252	.250	.247	.245	.242	.240	.237	.235
−38	.233	.230	.228	.226	.223	.221	.219	.217	.214	.212
−39	.210	.208	.206	.204	.201	.199	.197	.195	.193	.191
−40	.189	.187	.185	.183	.182	.180	.178	.176	.174	.172
−41	.170	.169	.167	.165	.163	.162	.160	.158	.157	.155
−42	.153	.152	.150	.149	.147	.145	.144	.142	.141	.139
−43	.138	.136	.135	.134	.132	.131	.129	.128	.127	.125
−44	.124	.122	.121	.120	.119	.117	.116	.115	.113	.112
−45	.111	.110	.109	.107	.106	.105	.104	.103	.102	.101
−46	.0994	.0984	.0973	.0962	.0951	.0941	.0931	.0920	.0910	.0900
−47	.0890	.0880	.0870	.0861	.0851	.0841	.0832	.0823	.0814	.0805
−48	.0795	.0787	.0778	.0769	.0760	.0752	.0743	.0735	.0727	.0718
−49	.0710	.0702	.0694	.0686	.0679	.0671	.0663	.0656	.0648	.0641
−50	.0633									

THE TROPICAL CYCLONE OF JUNE 16, 1934, IN LOUISIANA

By ISAAC MONROE CLINE

[Weather Bureau office, New Orleans, La., July 20, 1934]

The tropical cyclone of June 16, 1934, was attended by some features of special interest as it traveled north-northeastward over southeastern Louisiana. It moved into a barometric depression which covered the Gulf States, and in which the sea level barometer readings over Louisiana and Texas on the morning of the 16th were generally below 29.70 inches. The lowest reading at 8 a.m., 29.40 inches, was at Morgan City, La., At Del Rio, Tex., the barometer was 29.58 inches, only 0.18 of an inch higher than at Morgan City. The depression extended well westward into Mexico and over the southern Rocky Mountain region. The cyclone was of small diameter but destructive winds attended it to the right of the line along which the center traveled. It was of such small diameter and traveled with such speed that a destructive storm tide was not developed. A storm tide of 2 feet to 3 feet was built up with its passage on the coast between Grand Isle and Vermilion Bay. It moved in on the Louisiana coast with its center over Vermilion Bay in the forenoon of the 16th and traveled thence north-northeastward with the center passing over Jeanerette, Iberia Parish, where Rev. J. B. Gedbout reported a calm and the barometer 28.58 inches from 2 p.m. to 2:45 p.m. At Houma, La., the anemometer of the United States Department of Agriculture Experiment Station shows that the highest 5-minute velocity was 22 miles per hour, at 8:05 a.m. This was probably about the time that the front of the storm was moving in over Vermilion Bay. Morgan City reported the barometer 28.90 inches and the wind velocity 68 miles per hour from the southeast at 2 p.m., after which the pressure rose and the wind diminished. The center of the disturbance passed near but to the westward of Baton Rouge about 4:10 p.m. when the barometer read 28.795 inches. The air-line distance from Jeanerette to Baton Rouge is about 55 miles, which shows that the cyclone was traveling about 27 miles per hour. This is an unusually rapid rate of travel for these storms. At New Roads, to the left of the line followed by this disturbance, the barometer read 28.90 inches about 5 p.m. This place is 22 miles farther north than Baton Rouge.

Well in front, and for some distance to the right, of the path of the center of the cyclone the wind came in irregular, sudden, powerful gusts with a much greater and more destructive force than velocities recorded by anemometers indicated. These local squalls made their appearance several hours before there was any important fall in the barometer, and were the most destructive agents attending the cyclone.

Mr. A. B. Learned, of Natchez, Miss., reports that on the 16th before noon there was a severe local windstorm at Ferriday, La., 10 miles west of Natchez, which blew down some houses and unroofed others. The storm did not reach Natchez until some 10 or 12 hours later, with the lowest barometer 29.12 inches, between 10 p.m. and 11 p.m. of the 16th.

In New Orleans these gusts or local squalls appeared early in the forenoon of the 16th, and blew down substantial trees in different parts of the city. The highest wind velocity for a 5-minute period at the Weather Bureau office in New Orleans was 24 miles from the southeast at 2:53 p.m. At the Shushan Airport the velocity was 35 miles from the southeast at noon and 35 miles from the south-southeast at 2 p.m. The wind velocity was as great at Baton Rouge as at Morgan City. The cyclone did not diminish in intensity until after it passed Baton Rouge, where the highest velocity was 66 miles per hour, 2:40 to 2:50 p.m., reported by Prof. Fred B. Kniffen, of the School of Geology of the Louisiana State University. He says the wind was from the northeast from 6 a.m. till noon, east from noon till 2:40 p.m., then southeast till 4:30 p.m., and south with varying easterly and westerly components until 5:40 p.m. and after 5:40 p.m. from the southwest.

The warnings received in connection with this disturbance were given a thorough distribution. The order to hoist northeast storm warnings over the threatened area was received at New Orleans at 3:06 p.m. June 15. Besides other distribution it was given at once to the

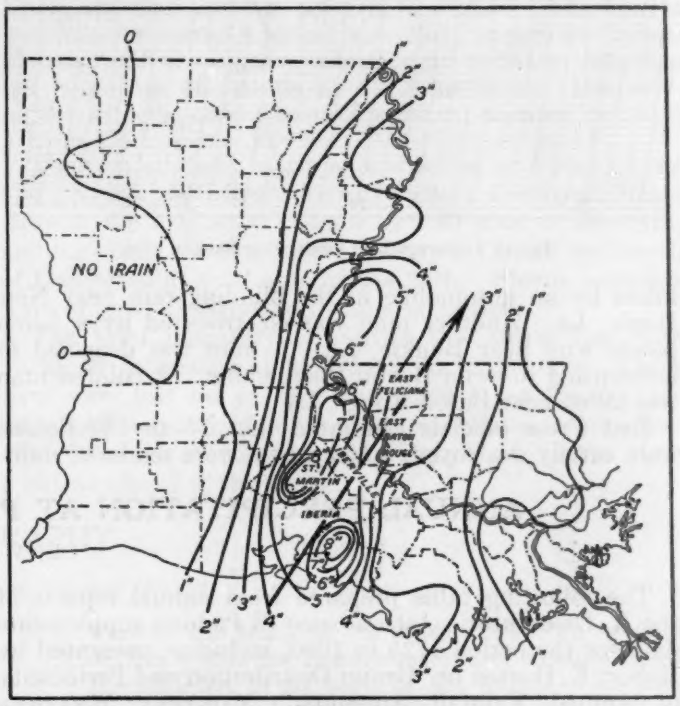

FIGURE 1.—Rainfall map of Louisiana for June 16, 1934. The arrow line shows the path of the tropical cyclone.

Houma-Terrebonne Chamber of Commerce and to the producing department of the Texas Co., Houma, La., for distribution by motor boat and special messenger (without expense to the Government) to fishing, shrimp, and oil-producing interests operating in the bays and bayous between Grand Isle and Atchafalaya Bay. The order to hoist hurricane warnings at 10:00 a.m., Grand Isle to Vermilion Bay, was given the widest possible distribution, by telephone, telegraph, and radiophone. The people of Grand Isle had been instructed to listen in for radiophone broadcasts at frequent intervals when a disturbance was approaching the Gulf Coast. The radiophone broadcasts made by WSMB, WDSU, and WWL were very effective throughout the entire region threatened with dangerous winds and high tides. At Grand Isle, which has neither telegraph nor telephone, the warnings were received by radiophone promptly and frequently. The radiophone managers were informed that the people had been told to look to them, and they gave commendable service. The

special observations, tide reports, etc., received at New Orleans were given to the radiophone stations and this information was broadcast. In this way the public was kept well informed concerning the storm, its intensity and progress.

Six persons in Louisiana lost their lives during the storm. Near the coast two small children were drowned by being washed from a raft on which their father was taking them from a shrimp platform. One man was killed by an automobile in the blinding rain near New Iberia, La. Another man was electrocuted by a fallen power wire near Bunkie, La. A man was drowned in attempting to swim Bayou Plaquemine. A colored man was killed near Baton Rouge, La.

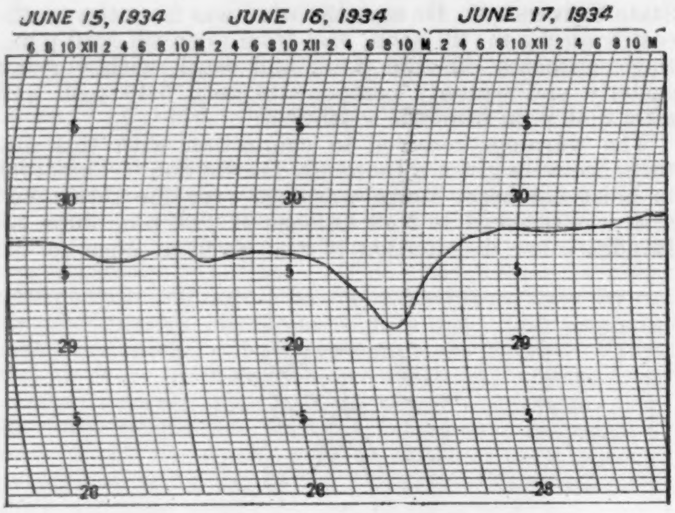

FIGURE 2.—Barogram for June 11–17 at Natchez, Miss.

Red Cross officials estimated that 75 to 150 houses were totally destroyed, 1,500 others were rendered uninhabitable, and between 3,000 and 7,000 were damaged more or less (Times-Picayune, June 20, 1934). A survey made by the Weather Bureau indicates that the total loss damage to buildings in Louisiana amounted to about $1,000,000.

Damage to shrimp-drying platforms on the coast, $75,000.

Damage to oil derricks on the coast, $30,000.

Damage to all kinds of crops, including pecans, is estimated at $1,500,000. Mr. C. W. Moore, marine surveyor, board of underwriters, says:

> On the morning of June 16, 1934, about 9:10 o'clock as no doubt you may recall, when you handed me your latest storm bulletin, I immediately returned to my office and telephoned our marine companies the information which you had given me. I also phoned to several of the towboat owners in the New Orleans harbor giving them your latest storm warning. I then called up my son, G. F. Moore, treasurer of the Dalton Co., Baton Rouge, La., and read your storm bulletin to him.
>
> Last week my son informed me that after he had gotten the storm warning through me, he at once ordered all valuable window displays in the Dalton Co. store removed to safety and had the windows reinforced.
>
> Your storm bulletin, which I had phoned him fully 5 hours in advance of the storm, gave them ample time to protect their valuable dress goods and other merchandise. It was then, he said, that they fully appreciated the splendid service rendered by the Weather Bureau office of New Orleans, as their loss was found to be nil.

METEOR TRAILS IN ANTARCTICA

LITTLE AMERICA, VIA SAN FRANCISCO, Calif.,
July 6, 1934.

To Dr. W. J. HUMPHREYS,
Weather Bureau, Washington, D.C.

Have observed drifts on four different meteor trains such as suggested your letter January 25. All these observations indicate a wind velocity of more than 100 miles per hour from west to east at altitude of nearly 100 miles.

(Signed) THOMAS C. POULTER.

ANNUAL PRECIPITATION AT PADUA, ITALY, 1901–33, INCLUSIVE

By W. W. REED

The following table prepared from annual reports of the R. Osservatorio Astronomico di Padova supplements data for the period 1725 to 1900, inclusive, presented by Robert E. Horton in "Group Distribution and Periodicity of Annual Rainfall Amounts," MONTHLY WEATHER REVIEW, October 1923, volume 51, page 516.

Annual precipitation, Padua, Italy

Year	Inches	Year	Inches
1901	39.61	1918	38.23
1902	33.50	1919	24.47
1903	31.50	1920	35.83
1904	31.26		
1905	47.48	1921	16.91
		1922	27.23
1906	32.24	1923	28.84
1907	28.19	1924	34.44
1908	22.52	1925	28.66
1909	36.38		
1910	42.34	1926	29.18
		1927	31.42
1911	35.69	1928	32.90
1912	30.00	1929	28.59
1913	33.87	1930	27.61
1914	30.44		
1915	37.15	1931	23.24
		1932	30.00
1916	44.56	1933	25.45
1917	29.22		

TROPICAL DISTURBANCE OF JULY 21-25, 1934

By C. L. MITCHELL

This disturbance was unprecedented, so far as is known, in that it was of extra-tropical origin, but moved southwestward into the Gulf of Mexico and assumed all of the characteristics of a disturbance of tropical origin. Its extreme southern position was 5° south of its place of formation. The nearest recorded approach to a development and movement of this character was that of October 1913, when a secondary disturbance that formed southeast of Nantucket, Mass., moved steadily southward and southwestward for several days and then westward, and passed inland on the South Carolina coast north of Charleston with all the characteristics of a tropical disturbance of moderate intensity.

On July 20 a disturbance of wide extent was advancing slowly eastward, with center over eastern Quebec and with slowly falling pressure southwestward to the Carolinas. The winds aloft, which had been westerly, changed to northerly as far south as Florida. By the morning of the 21st a further slight decrease in pressure along the South Carolina coast, together with a slight rise over Virginia and North Carolina, resulted in a wind shift line that extended from about 75 miles east of Cape Hatteras southwestward to Charleston. However, there was no material change in air mass as shown by airplane flights made at Washington, Norfolk, and Montgomery. The barometer at Wilmington and Savannah read 29.92 inches, and at Charleston 29.90 inches, so that a slight secondary disturbance was shown on the map at that place. As a rule, such minor disturbances quickly disappear, or else move off to the east or northeast; but with the upper air moving from the north and north-northeast over the South Atlantic States, this one was carried south-southwestward to the vicinity of Jacksonville by the evening of the 22d. At this time the wind at 8,000 feet elevation was 54 miles per hour from the east-northeast, and at Tampa 12 miles per hour from the northwest. This was the first evidence of the deepening of the disturbance, inasmuch as there was little pressure gradient at the surface.

During the night of the 22d-23d the disturbance crossed the Florida peninsula and entered the Gulf of Mexico. For nearly 48 hours it moved steadily in a west-southwesterly direction with slowly increasing intensity. It was then (8 p.m. July 24) centered about 200 miles southeast of Galveston and was apparently still moving west-southwestward. However, a corrected report received later from M.S. *Sharon* in lat. 26°8′ N., long. 93°6′ W., (the only vessel near or west of the center) indicated that the direction of movement had, since the 1 p.m. vessel reports, changed to west, so that the center the following morning was about 60 miles farther north than was indicated from the 8 p.m. reports of the 24th. The center moved inland a short distance north of Rockport, Tex., about noon of the 25th. The lowest barometer reading reported was 29.12 inches at Corpus Christi, and the highest official wind velocity, 52 miles per hour from the south, at the same place. However, higher velocities were undoubtedly experienced between Corpus Christi and Freeport.

The first advisory warning was issued at 9 p.m. of the 23d. Storm warnings were ordered displayed from Brownsville to Port O'Connor at 9:30 p.m. of the 24th, and hurricane warnings north of Corpus Christi and south of Galveston at 9:30 a.m. of the 25th. Storm warnings were ordered at Galveston at the same time.

The total monetary loss from this storm has been variously estimated at $1,000,000 to $2,000,000. Three lives were lost on or near the coast (1 at Texas City and 2 at Freeport), while 8 persons were killed in tornadoes that occurred at Morales and Wink, Tex., in the right front quadrant of the storm.

BIBLIOGRAPHY

C. FITZHUGH TALMAN, *in charge of Library*

RECENT ADDITIONS

The following have been selected from among the titles of books recently received as representing those most likely to be useful to Weather Bureau officials in their meteorological work and studies:

Brooks, Charles

The tornado of 1851, in Medford, West Cambridge and Waltham, Middlesex County, Mass. Being a report by Rev. Charles Brooks, and reports by other committees. Boston, J. M. Usher, 1852. 72 p. front. 15½ cm.

Clayton, Henry Helm

World weather and solar activity. Washington, The Smithsonian institution, 1934. 1. p. 1., 52 p. incl. illus. (maps), tables, diagrs., fold. maps. 24½ cm. (Smithsonian miscellaneous collections. v. 89, no. 15.) Publication 3245. At head of title: Roebling fund.

Curzon, Julian, *pseud*

The great cyclone at St. Louis and East St. Louis, May 27, 1896. Being a full history of the most terrifying and destructive tornado in the history of the world, with numerous thrilling and pathetic incidents and personal experiences of those who were in the track of the storm. Also an account of the wonderful manifestations of sympathy for the afflicted in all parts of the world. Compiled and edited by Julian Curzon. St. Louis, Cyclone publishing company [1896]. [3]-416 p. incl. illus., plates. 20 cm.

Fisk, Dorothy

Exploring the upper atmosphere. With an introduction by Henry Leopold Brose . . . illustrated by Leonard Starbuck. London, Faber and Faber, limited [1934]. 2 p. l., 7-166 p. incl. front., illus., diagrs. 20½ cm.

Manila. Harbor Board

The port of Manila, Philippine Islands. A yearbook. 1934- Manila, P. I. [1934-] v. 1. 55 p. illus. (part. fold.), tables. 23 cm. "Compiled, published, and distributed by the Manila Harbor board," 1934-. [Meteorology, pp. 25 ff. and 31 ff.]

Williamson, Robert M.

Visibility, a new element in meteorological observation. 1934. p. 93-99. 23 cm. (Excerpt: Tennessee academy of science. Journal. v. 9, no. 2. April, 1934.)

SOLAR OBSERVATIONS

SOLAR AND SKY RADIATION MEASUREMENTS DURING JULY 1934

By IRVING F. HAND, Assistant in Solar Radiation Investigations

For a description of instruments and their exposures, the reader is referred to the January 1932 REVIEW, page 26.

Table 1 shows that solar radiation intensities averaged slightly above normal for July at all three Weather Bureau stations.

Table 2 shows an excess in the total solar and sky radiation received on a horizontal surface at all stations except Madison, Chicago, Pittsburgh, and Miami. The cumulative data now show that the country as a whole is considerably above normal for the first 7 months of the year. This, of course, has been a most appreciable factor in causing the recent drought conditions.

Table 3 shows rather high turbidity factors and low water-vapor content of the atmosphere, as might be expected because of the unusual dryness of the soil.

Polarization measurements made on 8 days at Washington give a mean of 55 percent, with a maximum of 61 percent on the 7th. At Madison, measurements made on 8 days give a mean of 58 percent, with a maximum of 62 percent on the 28th. All the above values are slightly below the July normals.

TABLE 1.—*Solar radiation intensities during July 1934*

[Gram-calories per minute per square centimeter of normal surface]

WASHINGTON, D.C.

Date	Sun's zenith distance: 8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass A.M. 5.0	A.M. 4.0	A.M. 3.0	A.M. 2.0	*1.0	P.M. 2.0	P.M. 3.0	P.M. 4.0	P.M. 5.0	Local mean solar time
	e										e
	mm	cal	cal	cal	cal	cal	cal	cal	cal	cal	mm
July 3	17.37					1.12					15.65
July 5	18.59				0.86						21.28
July 6	20.57					1.20					22.00
July 7	19.23			0.88	1.05						20.57
July 16	16.20				.92	1.27					14.10
July 17	9.47		0.66	.79	1.00	1.36					10.97
July 18	15.11			.92	1.09						11.38
July 19	16.79				.90	1.31					19.89
July 21	20.57				.98	1.08					16.79
July 31	16.20			.84	1.01	1.28					15.65
Means			(.66)	.86	.98	1.23					
Departures			−.02	+.07	+.06	+.02					

* Extrapolated.

TABLE 1.—*Solar radiation intensities during July 1934*—Continued

MADISON, WIS.

Date	Sun's zenith distance: 8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass A.M. 5.0	A.M. 4.0	A.M. 3.0	A.M. 2.0	1.0	P.M. 2.0	P.M. 3.0	P.M. 4.0	P.M. 5.0	Local mean solar time
	e										e
	mm	cal	cal	cal	cal	cal	cal	cal	cal	cal	mm
July 2	11.81		0.85	0.96	1.11	1.33					11.81
July 7	9.47		.93	1.09	1.24	1.44					8.18
July 17	9.47		.83	.92	1.09	1.33					14.10
July 19	15.65					1.31					18.59
July 20	17.37				1.06	1.21					21.85
July 23	15.65				.89	1.30					21.85
July 24	17.96					1.36					16.20
July 25	19.23		.68	.83	1.00	1.26					17.96
July 28	8.81			1.07	1.28	1.49					9.14
July 30	10.59				1.22	1.42					10.59
July 31	10.97	0.63	.76	.89	1.07	1.37					10.59
Means		(.63)	.81	.96	1.11	1.35					
Departures		−.06	+.01	+.04	+.04	+.05					

LINCOLN, NEBR.

Date	8 a.m.	A.M. 5.0	A.M. 4.0	A.M. 3.0	A.M. 2.0	1.0	P.M. 2.0	P.M. 3.0	P.M. 4.0	P.M. 5.0	Noon
July 3	13.13				1.04	1.21					15.11
July 6	12.24						1.28	1.11	1.02	0.89	8.81
July 7	8.18		0.99	1.10	1.24	1.54	1.13	.96	.80	.66	10.59
July 10	12.68		.73	.88	1.02						14.10
July 12	17.96					1.33	1.04	.82	.70		13.61
July 14	15.11			.84	1.05	1.32	1.11	.93	.77	.61	13.61
July 16	14.60	0.68	.81	.95	1.11	1.28					9.83
July 17	16.20					1.26	1.03	.82	.67		13.61
July 18	10.21				1.11						7.57
July 19	8.81						1.01	.82	.68		6.76
July 20	7.29				1.04	1.31					5.79
July 21	9.83		.69	.84	1.05	1.26					9.83
Means		(.68)	.80	.92	1.08	1.31	1.10	.91	.77	.72	
Departures		−.02	+.02	+.02	±.00	±.00	+.03	+.02	+.01	+.01	

BLUE HILL OBSERVATORY OF HARVARD UNIVERSITY

Date	8 a.m.	A.M. 5.0	A.M. 4.0	A.M. 3.0	A.M. 2.0	1.0	P.M. 2.0	P.M. 3.0	P.M. 4.0	P.M. 5.0	Noon
July 2	14.1				1.00	1.39	1.13	0.98	0.84		10.6
July 3	18.0					1.19	.54				17.4
July 4	12.2				1.02	1.33	1.13				11.0
July 5	8.5					1.35					9.8
July 7	19.9				.89	1.11					19.2
July 8	12.7						1.15	1.04			11.8
July 9	9.5			1.01	1.20	1.45	1.23				9.5
July 11	12.2			1.12	1.23	1.35					20.6
July 12	11.8						1.23	1.01	.84		18.6
July 13	14.1				.74	1.21					16.8
July 16	14.6					1.42					12.7
July 17	9.1				1.20	1.43	1.13				7.6
July 18	9.5					1.43					6.3
July 19	11.0					1.35	1.00				9.5
July 22	10.6					1.39	1.24	1.10	.97		9.1
July 23	8.5						1.10				9.1
July 24	10.2					1.38	1.13	.90	.73		9.8
July 30	14.6					1.42	1.10				15.6
Means				1.06	1.04	1.35	1.09	1.01	.84		

TABLE 2.—*Average daily totals of solar radiation (direct+diffuse) received on a horizontal surface*

Week beginning—	Washington	Madison	Lincoln	Chicago	New York	Fresno	Pittsburgh	Fairbanks	Twin Falls	La Jolla	Miami	New Orleans	Riverside	Blue Hill	Frida Harbo
	Gram-calories per square centimeter														
1934	cal	cal	cal	cal	cal	cal	cal	cal	cal	cal	cal	cal	cal	cal	cal
July 2	662	477	587	440	512	771	431	379	688	452	513	386	617	590	645
July 9	594	470	598	440	526	761	438	360	733	517	530	448	627	616	489
July 16	607	493	650	(1)	612	751	520	340	680	466	503	505	619	616	545
July 23	436	541	574	(1)	346	714	510	366	625	650	462	378	574	390	592
	Departures from weekly normals														
July 2	+146	−51	+7	−22	+78	+70	−45	−52	+66	+10	−29	+4			
July 9	+100	−62	+22	−4	+75	+66	−50	−47	+127	+106	−8	+70			
July 16	+123	−24	+74		+191	+74	+33	−58	+82	+24	−37	+32			
July 23	−49	+33	+24		−77	+62	+28	−17	+43	+224	−72	+28			
	Accumulated departures on July 29														
	+2,793	+2,394	+6,888	+6,489	[2] +12,117	+6,300	−2,156	−537	+5,397	+12,796	−3,864	+6,447			

[1] Pyrheliometer broken.

[2] Readings reduced by 2½ percent since change in recorder characteristics.

TABLE 3.—*Total, I_m, and screened, I_y, I_r, solar radiation intensity measurements, obtained during July 1934, and determinations of atmospheric turbidity factor, β, and water-vapor content, w=depth in millimeters, if precipitated*

Date and hour angle	Solar altitude		Air mass	I_m	I_y	I_r	βI_{m-r}	βI_{y-r}	β_{mean}	$\frac{I_{w-o}}{1.94}$ (Percentage of solar constant)	$\frac{I_{w-o}-I_m}{1.94}$ (Percentage of solar constant)	w	Air-mass type
AMERICAN UNIVERSITY, WASHINGTON, D.C.													
July 6	°	′	*m*	*gr. cal.*	*gr. cal.*	*gr. cal.*						*mm*	
1:39 a	63	43	1.12	1.136	0.902	0.720	0.140	0.130	0.135	72.4	11.1	21	TG.
1:36 a	63	58	1.11	1.129	.905	.721	.148	.130	.139	72.0	11.9	30	
July 17													
5:22 a	20	20	2.86	.806	.670	.591	.112	.176	.144	48.5	5.7	2	PC.
5:17 a	21	17	2.74	.832	.671	.592	.095	.180	.138	50.0	5.6	2	PP aloft.
5:04a	23	46	2.47	.894	.753	.620	.095	.101	.098	59.4	11.8	14	
4:59 a	24	43	2.38	.928	.755	.622	.085	.105	.095	61.5	12.0	15	
4:55 a	25	30	2.32	.932	.771	.636	.092	.118	.105	60.0	10.4	9	
4:51 a	26	19	2.25	.941	.772	.637	.090	.124	.107	59.0	9.0	5	
4:47 a	27	03	2.20	.970	.794	.644	.085	.089	.087	63.7	12.1	16	
4:43 a	27	49	2.14	.965	.795	.645	.088	.092	.090	65.8	14.4	39	
July 31													
4:48 a	25	14	2.28	.927	.759	.619	.085	.089	.087	62.5	13.1	21	PC.
4:44 a	26	00	2.28	.946	.760	.620	.078	.092	.085	63.5	13.0	22	PP aloft.
3:34 a	39	35	1.57	1.130	.878	.700	.070	.088	.079	72.8	13.1	32	
3:29 a	40	33	1.54	1.141	.879	.701	.075	.091	.083	72.0	11.6	16	
2:20 a	53	23	1.25	1.112	.882	.699	.115	.115	.115	73.4	13.2	31	
2:18 a	53	54	1.24	1.141	.882	.699	.095	.118	.106	74.0	13.6	32	
BLUE HILL METEOROLOGICAL OBSERVATORY OF HARVARD UNIVERSITY													
July 2													
4:11 a	35	07	1.65	1.109	0.776	0.622	0.083	0.100	0.092	70.3	11.1	14.0	N_{PP}.
3:37 a	41	24	1.51	1.164	.803	.644	.076	.106	.091	72.3	10.3	10.0	
2:39 a	52	54	1.25	1.235	.860	.675	.084	.071	.078	77.6	11.8	25.0	
2:16 a	55	54	1.20	1.306	.910	.703	.069	.029	.049	82.7	13.1	40.0	
0:19 a	70	26	1.06	1.365	.955	.746	.071	.033	.052	83.6	11.9	43.0	
1:37 a	62	10	1.13	1.312	.905	.699	.055	.037	.046	83.5	13.6	47.0	N_{PC}.
4:04 p	36	31	1.68	1.191	.833	.656	.054	.058	.056	76.0	12.5	24.0	
4:26 p	32	19	1.87	1.150	.828	.649	.059	.048	.054	74.3	13.0	24.0	
July 4													
3:12 a	45	09	1.41	1.270	.891	.696	.055	.043	.049	80.2	12.5	28.0	P_C.
2:57 a	48	36	1.33	1.312	.920	.719	.053	.037	.045	81.7	12.2	27.0	
July 5													
1:45 p	60	44	1.14	1.302	.888	.695	.140	.063	.102	75.8	6.4	2.9	N_{PC}.
3:28 p	42	54	1.47	1.190	.826	.665	.080	.101	.090	72.9	9.5	7.3	T_c aloft.
July 7													
1:17 a	64	47	1.10	1.081	.767	.608	.166	.188	.177	68.3	10.7	19.0	T_C.
July 8													
5:24 p	21	21	2.74	1.067	.736	.582	.073	.047	.060	66.5	10.6	5.4	P_C.
5:39 p	17	55	3.23	1.015	.729	.578	.026	.040	.033	70.3	16.2	60.0	
July 9													
3:10 a	45	56	1.39	1.329	.922	.724	.033	.033	.033	83.1	12.9	35.5	P_C.
2:32 a	57	42	1.18	1.372	.941	.729	.036	.022	.029	85.8	12.2	25.0	
1:10 a	66	10	1.09	1.428	.974	.760	.032	.025	.028	86.7	10.6	19.0	
0:09 p	70	04	1.06	1.425	.980	.764	.036	.019	.028	87.1	11.2	35.0	
1:27 p	69	24	1.07	1.418	.959	.749	.032	.031	.032	86.5	10.9	22.0	N_{PC}.
3:33 p	41	43	1.50	1.343	.919	.720	.035	.028	.032	82.4	10.9	14.0	
4:22 p	32	39	1.86	1.262	.885	.705	.033	.045	.039	78.5	11.0	13.0	
July 10													
3:35 a	41	17	1.51	1.256	.880	.697	.056	.058	.057	77.5	10.6	10.6	N_{PC}.
2:17 a	55	11	1.22	1.349	.921	.727	.044	.057	.050	82.1	10.2	9.9	
0:27 a	69	14	1.07	1.407	.962	.752	.043	.034	.038	85.6	10.5	18.0	
1:26 p	69	18	1.07	1.401	.958	.738	.033	.008	.020	88.2	13.6	49.0	N_{PC}.
3:07 p	46	24	1.38	1.313	.904	.705	.039	.037	.038	82.5	12.6	30.0	
4:30 p	31	02	1.94	1.227	.872	.672	.030	.008	.019	81.4	16.0	60+	
July 11													
4:00 a	36	35	1.67	1.264	.886	.702	.043	.045	.044	78.3	11.0	14.0	N_{PC}.
3:21 a	43	46	1.44	1.260	.880	.698	.062	.062	.062	80.7	13.6	38.0	
0:06 a	69	51	1.06	1.335	.908	.710	.075	.062	.068	81.7	9.6	12.0	
July 13													
2:36 a	51	38	1.27	1.048	.749	.594	.150	.142	.146	68.5	12.7	34.0	N_{PC}.
0:39 a	67	05	1.09	1.154	.808	.641	.136	.136	.136	73.0	11.6	39.0	T_c aloft.
July 24													
3:15 a	43	40	1.45	1,328	.927	.729	.045	.035	.040	81.2	9.5	8.0	N_{PC}.
2:03 a	56	03	1.20	1.380	.963	.760	.052	.041	.046	83.1	8.7	27.0	T_c aloft.
July 30													
4:50 p	25	56	2.28	1.068	.778	.609	.056	.046	.051	71.0	13.4	27.0	P_C, T_c aloft.

Atmospheric conditions.
July 6. Wind, SW. 7; temperature, 22°C., visibility, 12 miles.
July 17. Wind, NE. 10; temperature, 21° C., visibility, 20 miles.
July 31. Wind, SW. 3; temperature, 20° C., visibility, 30 miles.

TABLE 3.—*Total, I_m, and screened, I_y, I_r, solar radiation intensity measurements, obtained during July 1934, and determinations of the atmospheric turbidity factor, β, and water-vapor content, w=depth in millimeters, if precipitated.*—Continued

Atmospheric conditions during solar radiation measurements—Blue Hill Meteorological Observatory of Harvard University

Date and time from apparent noon	Air temperature	Wind (Beaufort scale)	Visibility. Scale, 0-10	Sky blueness	Cloudiness and remarks
July 1934	°C.				
2; 4:11 a	23.3	WNW 4	8	7	2 Ci.
2; 3:37 a	25.6	WNW 3	8	6	1 Ci.
2; 2:16 a	25.6	WNW 4	8	7	1 Ci.
2; 0:19 a	26.7	WNW 4	8	8	Few Ci; 1 Cu.
2; 1:37 p	27.8	WNW 4	9	6	1 Ci, 2 Cu. Wind gusty.
2; 4:04 p	28.3	W 4	8+	8	3 Cu; Wind gusty.
4; 3:12 a	21.7	NW 2	9	6	1 Ci, 1 Cu.
5; 1:45 p	26.1	WSW 4	9	6	Few Ci, 2 Acu.
5; 3:28 p	22.2	SWxW 5	9	6	2 Ci, 3 Acu, few Cu.
7; 1:17 a	29.4	SW 3	6-7	------	Few Ci, Cu, Stcu, Frcu; moderate haze.
8; 5:24 p	22.2	SExE 2	9	7	3 Acu, few Cu.
9; 3:10 a	18.6	NNE 6	8	5	1 Acu.
9; 1:10 a	19.7	NE 4	9	6	1 Acu; lt. hz.; smoke to the N-SW.
9; 1:27 p	20.3	ENE 2	9	7	1 Acu, few Frcu; smoke over Boston.
9; 4:22 p	21.9	E 1	9	7	2 Ci, few Cu.
10; 2:17 a	18.3	ENE 2	8	5	Few Acu, Cu.
10; 0:27 a	18.3	ENE 2	8	5	1 Stcu.
10; 3:07 p	20.0	NE 3	9	5	1 Cu. Smoke NW of Boston.
11; 4:00 a	18.3	SSE 1	8	5	2 Ci in NW; smoke on horizon.
11; 3:21 a	20.0	SExS 1	7-8	5	2 Ci in NW; smoke on horizon.
11; 0:06 a	27.2	SE 1	8	4	10 Ci, very thin sheet.
13; 2:36 a	20.6	SSW 2	7-8	------	2 Ci, few Cu, moderate haze.
13; 0:39 a	25.0	SSW 2	8	------	4 Stcu.
24; 3:15 a	21.7	ENE 1	8	5	2 Ci, few Cu.
24; 2:03 a	21.7	N 1	--------	------	4 Ci, few Cu.
30; 4:30 p	22.4	ENE 3	8	------	1 Acu in south; few Ci in southeast.

POSITIONS AND AREAS OF SUN-SPOTS

Communicated by Capt. J. F. Hellweg, U.S. Navy, Superintendent U.S. Naval Observatory. Data furnished by the U.S. Naval Observatory in cooperation with Harvard and Mount Wilson Observatories. The difference in longitude is measured from the central meridian, positive west. The north latitude is positive. Areas are corrected for foreshortening and are expressed in millionths of the sun's visible hemisphere. The total area for each day includes spots and groups]

TABLE 3.—*Total, I_m, and screened, I_y, I_r, solar radiation intensity measurements, obtained during July 1934, and determinations of the atmospheric turbidity factor, β, and water-vapor content, w=depth in millimeters, if precipitated.*—Continued

POSITIONS AND AREAS OF SUN-SPOTS—Continued

Date	Eastern standard time	Heliographic			Area		Total area for each day	Observatory
		Diff. in longitude	Longitude	Latitude	Spot	Group		
1934	h. m.	°	°	°				
July 1	12 0	No spots		------	------	------	------	Mount Wison.
July 2	11 14	No spots		------	------	------	------	U.S. Naval.
July 3	11 18	No spots		------	------	------	------	U.S. Naval.
July 4	12 20	No spots		------	------	------	------	U.S. Naval.
July 5	11 4	No spots		------	------	------	------	U.S. Naval.
July 6	14 30	−80.5	271.8	+21.5	448	------	448	Harvard.
July 7	11 15	−68.0	272.8	+24.0	153	------	153	Mount Wilson.
July 8	13 4	−55.5	271.2	+24.0	------	93	93	U.S. Naval.
July 9	11 9	−42.5	272.0	+24.0	------	131	131	U.S. Naval.
July 10	14 28	−28.0	271.4	+24.0	------	131	131	U.S. Naval.
July 11	11 15	−79.0	209.0	+2.0	46	------	------	U.S. Naval.
		−15.5	272.5	+24.0	123	------	169	
July 12	14 55	−63.0	209.7	+1.5	46	------	------	U.S. Naval.
		−1.0	271.7	+24.0	108	------	154	
July 13	13 25	−50.0	210.3	+1.0	69	------	------	U.S. Naval.
		+11.0	271.3	+24.0	108	------	177	
July 14	11 5	−37.5	210.8	+1.0	69	------	------	U.S. Naval.
		+23.0	271.3	+24.0	108	------	177	
July 15	18 0	−20.0	211.3	+1.0	122	------	------	Mount Wilson.
		+41.0	272.3	+25.0	137	------	259	
July 16	11 8	−11.0	210.9	+1.0	62	------	------	U.S. Naval.
		+49.5	271.4	+25.0	108	------	170	
July 17	13 20	+3.0	210.4	+1.5	54	------	------	U.S. Naval.
		+63.0	270.4	+25.0	62	------	116	
July 18	11 13	+17.0	212.4	+1.5	46	------	------	U.S. Naval.
		+76.0	271.4	+25.0	46	------	92	
July 19	11 16	+30.0	212.1	+1.5	39	------	39	U.S. Naval.
July 20	13 26	+44.0	211.7	+1.5	8	------	8	U.S. Naval.
July 21	------	No spots		------	------	------	------	Harvard.
July 22	13 48	No spots		------	------	------	------	U.S. Naval.
July 23	11 17	No spots		------	------	------	------	U.S. Naval.
July 24	13 21	No spots		------	------	------	------	U.S. Naval.
July 25	11 38	No spots		------	------	------	------	U.S. Naval.
July 26	13 16	No spots		------	------	------	------	U.S. Naval.
July 27	9 0	No spots		------	------	------	------	Mount Wilson.
July 28	11 10	−10.0	53.0	+11.0	------	5	------	Mount Wilson.
		+10.0	73.0	−25.0	------	5	10	
July 29	11 15	+23.0	72.8	−25.0	------	7	7	Mount Wilson.
July 30	11 32	No spots		------	------	------	------	U.S. Naval.
July 31	11 29	No spots		------	------	------	------	U.S. Naval.
Mean daily area for 31 days	------	------	------	------	------	------	75	

PROVISIONAL SUN-SPOT RELATIVE NUMBERS FOR JULY 1934

(Dependent alone on observations at Zurich and its station at Arosa)

[Data furnished through the courtesy of Prof. W. Brunner, Eidgen. Sternwarte, Zurich, Switzerland]

July 1934	Relative numbers	July 1934	Relative numbers	July 1934	Relative numbers
1	0	11	d 24	21	7
2	0	12	b 24	22	0
3	0	13	25	23	0
4	0	14	24	24	7
5	0	15	17?	25	8
6	d 8	16	23	26	0
7	8	17	17	27	7?
8	11	18	17	28	7
9	11	19	17	29	0
10	18	20	8	30	0
				31	0

Mean: 31 days=9.3.

b=Passage of a large group or spot through the central meridian.
d=Entrance of a large or average-sized ctener of activity on the east limb.

AEROLOGICAL OBSERVATIONS

[Aerological Division, D. M. Little, in charge]

By L. T. SAMUELS

It will be noted that table 1 contains marked differences both in the names and number of stations from those given heretofore. This is owing to the expanded aerological program which became effective July 1, 1934, according to which daily flights are made at a number of Army and Navy stations in addition to those at Weather Bureau stations. The latter have been relocated in all cases, except Omaha, in order to obtain a better distribution over the country as a whole. Also, the times of observations, and maximum heights attained, at the military stations have been standardized to conform to those of the Weather Bureau in practically all cases. Because of the large number of new stations, it is impossible at present to determine departures from the normals, except in a few cases.

The free-air temperatures for July averaged highest over San Diego and lowest over Spokane. It is interesting to note the free-air temperatures at Billings and Cheyenne as compared with those far to the south. The action of insolation over this Plateau to cause higher temperatures of the air for considerable elevations above the surface, in contrast to those of the free air over adjacent low-lying regions for corresponding elevations above sea level, is thus brought out. Moreover, Cheyenne showed the most pronounced average temperature inversion directly off the surface of all the stations.

Free-air relative humidities averaged highest over the southeastern section of the country and lowest over the middle Pacific coast.

Free-air resultant winds for the month deviated most from normal over the southern part of the country, where velocities were light and directions variable. Resultant velocities at the higher levels generally exceeded the normals along the Pacific coast and at a few inland stations. Resultant directions were close to normal at most stations.

TABLE 1.—*Free-air temperatures and relative humidities obtained by airplanes during July 1934*

Station	Altitude (meters) m.s.l.																	
	Surface		500		1,000		1,500		2,000		2,500		3,000		4,000		5,000	
	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal
TEMPERATURE (°C.)																		
Billings, Mont.[1] (1,090 m)	18.0						20.5		18.7		15.7		12.2		4.3		−3.7	
Boston, Mass.[2] (6 m)																		
Cheyenne, Wyo.[1] (1,873 m)	15.8								18.0		20.0		16.2		6.8		−2.5	
Fargo, N.Dak.[1] (274 m)	15.5		18.4		19.1		17.1		14.8		12.2		9.2		2.4		−4.3	
Fort Crockett (Galveston), Tex.[3 4] (3 m)	26.3		25.2		23.0		20.5		17.3		14.3		10.9		4.5		−1.6	
Kelly Field (San Antonio), Tex.[3] (211 m)	23.9		23.6		22.3		20.5		17.6		14.3		11.1		4.8		−1.3	
Lakehurst, N.J.[5 6] (3 m)																		
Maxwell Field (Montgomery), Ala.[3] (52 m)	24.1		25.1		22.4		19.1		16.2		13.0		9.8		3.4		−2.5	
[*] Mitchel Field (Hempstead, L. I.), N.Y.[3] (39 m)	21.1		22.7		19.9		16.8		13.9		10.5		7.5		1.5		−4.7	
Murfreesboro, Tenn.[1] (174 m)	22.7		21.0		19.8		17.3		14.4		11.4		8.2		2.0		−4.1	
Norfolk, Va.[5] (3 m)	24.1	−0.9	23.6	−0.3	21.5	−0.3	18.8	−0.3	15.7	−0.1	12.7	−0.3	9.6	−0.6	3.7	−0.6	−2.3	−0.6
Oklahoma City, Okla.[1] (391 m)	24.3		25.9		26.9		23.7		20.1		16.5		12.7		5.5		−1.1	
Omaha, Nebr.[1] (300 m)	23.1		24.7		26.9	+5.6	24.3	+5.9	20.9	+5.5	16.9	+4.7	12.8	+3.9	4.9	+2.6	−2.3	+1.3
Pearl Harbor, Hawaii[5] (5 m)	23.4	−2.7	21.7	−1.1	18.2	−0.9			12.9	−1.1			9.0	−1.9	3.8	−2.5	−1.4	−2.4
Pensacola, Fla.[5] (2 m)																		
Philadelphia, Pa.[5 6] (3 m)																		
San Diego, Calif.[5] (5 m)	18.9	−2.2	17.8	−0.7	20.9	−1.3			21.8	+0.4			15.5	−1.9	8.2	−1.8	1.6	−1.8
Scott Field (Belleville), Ill.[3] (135 m)	22.6		26.6		25.6		22.0		18.2		14.8		10.9		2.6		−3.9	
Seattle, Wash.[5] (8 m)																		
Selfridge Field (Mt. Clemens), Mich.[3] (177 m)	19.3		22.1		20.9		18.3		15.7		12.9		10.1		4.2		−2.0	
Spokane, Wash.[7] (596 m)	14.9				18.5		16.2		12.3		8.3		4.8		−2.0		−8.6	
Sunnyvale, Calif.[5] (6 m)	16.5		14.4		17.3				18.4				12.0		3.9			
Washington, D.C.[5] (2 m)	21.6	−2.7	21.7	−0.6	21.1	+0.7			17.1	+2.2			11.2	+2.1	4.4	+1.2	−2.5	+1.1
Wright Field (Dayton), Ohio[3] (244 m)	21.2		23.0		23.5		20.6		17.5		14.2		10.9		4.3		−2.0	
RELATIVE HUMIDITY (PERCENT)																		
Billings, Mont.[1] (1,090 m)	53						47		45		46		47		51		52	
Boston, Mass.[2] (6 m)																		
Cheyenne, Wyo.[1] (1,873 m)	55								51		40		38		43		51	
Fargo, N.Dak.[1] (274 m)	81		64		50		46		42		40		40		42		46	
Fort Crockett (Galveston), Tex.[3 4] (3 m)	86		80		64		55		54		52		53		52		52	
Kelly Field (San Antonio), Tex.[3] (211 m)	89		87		71		60		57		54		52		47		45	
Lakehurst, N.J.[5 6] (3 m)																		
Maxwell Field (Montgomery), Ala.[3] (52 m)	92		72		73		73		68		66		66		64		59	
[*] Mitchel Field (Hempstead, L. I.), N.Y.[3] (39 m)	86		66		65		62		57		53		54		54		51	
Murfreesboro, Tenn.[1] (174 m)	92		75		69		66		66		61		59		53		52	
Norfolk, Va.[5] (3 m)	88	+10	79	+9	73	+9	72	+8	70	+9	69	+10	66	+12	61	+12	54	+12
Oklahoma City, Okla.[1] (391 m)	66		58		45		44		46		49		53		54		53	
Omaha, Nebr.[1] (300 m)	65	0	59	−4	46	−13	44	−14	43	−13	44	−11	47	−7	53	+1	53	+1
Pearl Harbor, Hawaii[5] (5 m)	82	+14	79	+4	82	0			67	−4			41	−1	29	+1	22	+1
Pensacola, Fla.[5] (2 m)																		
Philadelphia, Pa.[5 6] (3 m)																		
San Diego, Calif.[5] (5 m)	85	+9	83	+3	58	+8			35	+4			42	+3	46	0	45	0
Scott Field (Belleville), Ill.[3] (135 m)	79		61		57		61		62		57		58		60		55	
Seattle, Wash.[5] (8 m)																		
Selfridge Field (Mt. Clemens), Mich.[3] (177 m)	76		57		54		54		53		49		44		40		38	
Spokane, Wash.[7] (596 m)	57				43		41		44		47		46		45		49	
Sunnyvale, Calif.[5] (6 m)	76		79		59				27				23		19			
Washington, D.C.[5] (2 m)	84	+11	78	+10	67	+4			71	+7			62	+4	57	+6	54	+6
Wright Field (Dayton), Ohio[3] (244 m)	83		66		51		53		50		49		49		48		42	

[1] Weather Bureau.
[2] Massachusetts Institute of Technology.
[3] Army.
[4] June to November, inclusive, only.
[5] Navy.
[6] Lakehurst and Philadelphia alternate daily.
[7] National Guard.
[*] For Aug. 18–31, inclusive.

Observations taken at 5:00 a.m., 75th meridian time, except along the Pacific coast and Hawaii, where they are taken at 5:00 a.m., local standard time.

TABLE 2.—*Free-air resultant winds (meters per second) based on pilot-balloon observations made near 7 a.m. (E.S.T.) during July 1934*

[Wind from N=360°, E=90°, etc.]

Altitude (m) m.s.l.	Albuquerque, N. Mex. (1,554 m)		Atlanta, Ga. (309 m)		Bismarck, N. Dak. (518 m)		Brownsville, Tex. (7 m)		Burlington, Vt. (132 m)		Cheyenne, Wyo. (1,873 m)		Chicago, Ill. (192 m)		Cleveland, Ohio (245 m)		Dallas, Tex. (154 m)		Havre, Mont. (762 m)		Jacksonville, Fla. (14 m)		Key West, Fla. (11 m)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°		°		°		°		°		°		°	
Surface	360	1.3	291	1.3	49	1.4	151	1.7	184	2.0	281	3.5	264	0.2	188	1.6	173	2.7	254	0.8	240	1.2	131	2.0
500			298	3.9			170	9.1	232	3.0			231	1.5	230	2.8	209	9.5			272	3.2	130	3.5
1,000			299	4.4	144	3.9	171	9.2	287	4.1			240	4.0	275	4.0	204	8.3	267	1.5	259	2.3	132	3.3
1,500			308	3.3	230	1.9	176	7.8	289	6.8			263	6.1	276	5.6	190	4.5	292	2.2	250	1.1	140	2.5
2,000	129	1.7	301	2.4	272	3.6	163	6.8	291	9.6	269	5.0	275	7.0	288	7.0	156	2.7	289	4.1	223	0.6	129	2.7
2,500	182	1.9	305	2.3	287	5.1	164	4.7	294	9.5	253	4.8	280	7.7	291	8.1	126	2.3	269	5.5	229	0.8	131	2.4
3,000	227	2.2	309	0.9	288	6.8	144	3.0	290	10.5	250	4.2	289	8.3	294	8.7	110	2.2	251	7.3	229	0.7	105	2.0
4,000	292	1.5	157	0.5	285	9.2	122	3.2	291	7.7	276	3.6	290	8.0	289	9.8	116	2.6	249	11.9	208	0.8	100	1.7
5,000	37	1.2	34	1.3	298	10.3	104	2.9	294	8.6	275	7.0	295	9.7	290	12.6	114	2.8	251	14.6	305	0.4	360	1.0

Altitude (m) m.s.l.	Los Angeles, Calif. (217 m)		Medford, Oreg. (410 m)		Memphis, Tenn. (83 m)		New Orleans, La. (19 m)		Oakland, Calif. (8 m)		Oklahoma City, Okla. (402 m)		Omaha, Nebr. (306 m)		Phoenix, Ariz. (338 m)		Salt Lake City, Utah (1,294 m)		Sault Ste. Marie, Mich. (198 m)		Seattle, Wash. (14 m)		Washington, D.C. (10 m)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°		°		°		°		°		°		°	
Surface	68	0.1	302	0.8	186	1.3	267	1.0	289	1.2	172	3.4	88	1.0	69	1.3	151	4.1	359	0.4	124	1.0	195	0.1
500	113	1.7	289	1.4	243	6.2	237	3.3	262	2.9	189	6.8	164	2.6	263	0.8			302	0.4	171	0.5	256	1.6
1,000	16	0.9	287	1.9	257	3.7	216	2.8	300	4.9	219	12.3	214	7.7	261	2.2			298	3.6	85	0.6	307	2.3
1,500	293	2.2	234	0.4	276	1.9	212	3.5	259	3.1	215	2.0	238	9.1	267	1.5	161	5.2	286	5.6	286	1.4	296	4.3
2,000	246	2.2	199	1.7	307	0.6	204	3.8	242	3.2	226	3.9	247	9.6	239	1.0	175	4.9	294	7.4	282	3.1	293	6.0
2,500	207	3.2	214	5.3	89	0.7	218	3.5	212	4.8	215	2.0	253	7.4	177	1.1	198	3.6	298	9.1	295	3.1	294	6.7
3,000	184	3.5	212	7.9	91	1.5	209	3.3			187	1.4	262	6.7	157	2.0	234	3.5	298	9.3	276	3.6	290	8.1
4,000	168	4.4	226	9.7	70	2.6	259	3.1			163	1.5	279	7.5	146	3.3	254	5.3	304	12.7	249	4.8	292	8.0
5,000	161	4.8	219	11.1			177	0.9			59	2.3	311	13.6	128	4.9	232	7.5	305	11.2	260	4.0	293	7.6

RIVERS AND FLOODS

By RICHMOND T. ZOCH

(River and Flood Division, MONTROSE W. HAYES, in charge)

A few minor floods occurred in Pennsylvania, South Carolina, and Mississippi; practically no damage was caused by these floods. A moderate flood occurred in the Nolichucky River in Tennessee; more than $175,000 of damage was done there.

Most of the rivers of the United States were low. The lowest stages of record for the month of July were recorded in the Missouri River at Sioux City, Kansas City, and Hermann; in the Ohio River at Cairo, and in the Mississippi River at Keokuk, Hannibal, Grafton, St. Louis, Chester, Memphis, Helena, and Vicksburg. At Little Rock, Ark., the lowest stage of record for all months was recorded. These low stages do not necessarily mean comparatively low discharges, as the following remarks of the official in charge at Little Rock show:

> This office has not received any statement of the number of second-feet passing, but think it is about the same as in previous years when the river was at extreme low water, about 800 or 1,000 second-feet. The channel has been cutting a shorter course about 2 miles below the gage and it is probable that the resulting increased rate of flow would cut the channel deeper, letting the pool opposite Little Rock down.

Heavy rains over the Bear Creek watershed near Denver, Colo., resulted in floods which caused the loss of six lives and over $50,000 of property.

Table of flood stages for July 1934

[All dates are in July]

River and station	Flood stage	Above flood stages—dates		Crest	
		From—	To—	Stage	Date
ATLANTIC SLOPE DRAINAGE	*Feet*			*Feet*	
Lackawaxen: Hawley, Pa.	6	28	28	11.0	28
		12	14	13.5	13
Santee: Rimini, S.C.	12	19	21	13.4	21
		27	27	12.0	27
Savannah: Ellenton, S.C.	14	14	14	14.9	14
EAST GULF OF MEXICO DRAINAGE					
Pearl:					
Edinburgh, Miss.	20	9	12	21.6	10
Jackson, Miss.	18	16	20	19.6	18
MISSISSIPPI SYSTEM					
Ohio Basin					
Nolichucky: Embreeville, Tenn.	10	15	15	12.6	15

WEATHER OF THE ATLANTIC AND PACIFIC OCEANS

[The Marine Division, W. F. McDONALD in charge]

NORTH ATLANTIC OCEAN

By H. C. HUNTER

Atmospheric pressure.—The pressure during July 1934 averaged remarkably near normal in all parts of the North Atlantic Ocean. Pressure was comparatively high during part of the first decade over most northern sections, and the final decade was a period of rather high pressure over middle and lower latitudes. On the 26th the French steamship *Eliane L. D.* noted a reading of 30.72 inches near latitude 47° north, longitude 25° west, the highest so far reported during the month.

In general the lowest pressures occurred about the middle of the month. The lowest reading so far reported, 28.94 inches, was observed on the 15th, by the German motorship *Skagerrak,* as described below.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure (sea level) at selected stations for the North Atlantic Ocean and its shores, July 1934*

Stations	Average pressure	Departure	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Julianehaab, Greenland	29.78	----------	30.00	26	29.49	10
Reykjavik, Iceland	29.80	−0.04	30.07	8	29.35	31
Lerwick, Shetland Islands	29.90	+.10	30.35	8	29.46	28
Valencia, Ireland	30.04	+.06	30.40	2	29.45	31
Lisbon, Portugal	30.01	−.01	30.11	25	29.94	6, 16
Madeira	30.08	+.03	30.17	25	29.96	16
Horta, Azores	30.27	.00	30.52	25, 26	30.05	30
Belle Isle, Newfoundland	29.80	−.07	30.12	10	29.26	1
Halifax, Nova Scotia	29.95	.00	30.46	10	29.74	17, 22
Nantucket	29.95	−.03	30.37	10	29.74	16
Hatteras	30.00	−.01	30.22	9	29.75	14
Bermuda	30.14	−.04	30.30	28, 29	29.94	14
Turks Island	30.05	−.02	30.12	28	29.98	25
Key West	30.02	−.01	30.13	28	29.91	18
New Orleans	30.01	+.01	30.14	16	29.79	23

NOTE.—All data based on a.m. observations only, with departures compiled from best available normals related to time of observation, except Hatteras, Key West, Nantucket, and New Orleans, which are 24-hour corrected means.

Cyclones and gales.—To the northward of the 44th parallel a few vessels encountered fresh gales (force 8) in different parts of the ocean on scattered dates, but none of these gales was of general importance. For the other portions of the Atlantic, interest is concentrated on two well-marked storms. These were not felt, as far as can be ascertained, anywhere south of the 25th parallel of latitude; yet they exhibited many features characteristic of the severe storms which often start in North Atlantic tropical waters during the summer, and move thence into temperate waters.

On the 10th, there were signs of a small LOW, centered not far eastward of Jacksonville, Fla. During the next 3 days moderate increase in energy, and gradual progress to northeastward were indicated, and during the late hours of the 13th, 2 vessels bound from New York to Puerto Rico met fresh to whole gales in latitude about 32° north, longitude 71° west. During the 14th, moderately strong southerly winds prevailed at Bermuda.

The storm continued to northeastward and became the southeastward prolongation of a large LOW area that extended over regions adjacent to Hudson Bay. On the 15th, winds of great strength were noted on the chief steamship lanes south and east of Sable Island. The German motorship *Skagerrak* recorded force 12 on the forenoon of the 15th, near 40° N., 60° W., the only instance of winds of hurricane force reported by any ship during the whole month in Atlantic waters. Later in the day the American S.S. *City of Hamburg* and the French liner *Paris* encountered gales of force 11 at locations to northeastward of the *Skagerrak's* position. The barometric minimum of the *Skagerrak,* was 28.94 inches, considerably lower than any other report received from the Atlantic during July. (Chart VIII presents the weather conditions on the 15th.)

The following morning the storm was centered not far from Cape Race, and the intensity seemed considerably diminished; after the morning of the 16th it no longer stood out distinctly as a feature of the weather situation over the Atlantic.

The other noteworthy storm may be recognized in development on the evening of the 21st, when pressure was low at and near Savannah, Ga. This disturbance pursued an extraordinary course southwestward across Florida into the Gulf. The progress at first was slow, the center still being near Jacksonville on the evening of the 22d, with intensity more marked than the day before; but later movement was more rapid. When well out from the coast of the Gulf, the storm turned to a westward course.

The morning of the 25th found this storm centered not far east of Corpus Christi, Tex., with further increase of energy (see chart IX). Thereafter further westward movement brought the center inland across the Texas coast between Corpus Christi and Galveston, with high tide and destructive winds.

The highest wind reported from the Gulf of Mexico during this storm was of force 10, noted a short distance to westward of the 90th meridian during the afternoon of the 24th. No marine casualty of consequence has come to notice as occurring on the open Gulf because of this storm; but in Galveston Bay one steamship and a barge were reported swept aground, though each was later readily refloated. The effects of this storm on the coast and inland are discussed elsewhere in this issue.

No storm whatever was reported from the western Atlantic waters south of the Tropic of Cancer during the month.

Fog.—There was considerably more fog over most of the North Atlantic steamship lanes between our northern ports and northwestern Europe than there had been during June. As a result the amount during July was not far from normal near mid-ocean, but usually a little less than normal in the eastern portion. On the Grand Banks there was more fog than normal, notably in the 5° square between 40° and 45° north, 45° and 50° west, where fog was noted during 25 days, including every day save one from the 11th to the last day of the month, inclusive.

In the waters adjacent to the North and Middle Atlantic States fog during July 1934 was less prevalent than it had been during the preceding month, and for the most part was a little less frequent than is normally the case during July.

OCEAN GALES AND STORMS, JULY 1934

Vessel	Voyage		Position at time of lowest barometer		Gale began	Time of lowest barometer	Gale ended	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Direction and highest force of wind	Shifts of wind near time of lowest barometer
	From—	To—	Latitude	Longitude									
NORTH ATLANTIC OCEAN			° ′	° ′				Inches					
Lustrous, Br. S.S.	Preston, England.	New York	44 18 N.	40 56 W.	July 1	3p, July 1	July 1	[2] 29.65	SSE	W, 4	S	SSE, 8	SSW-W.
Pres. Harding, Am. S.S.	Cobh	do	48 16 N.	33 23 W.	July 2	4a, 2	July 2	29.79	W	S, 7	W	W, 8	SE-SW.
Cliffwood, Am. S.S.	Copenhagen	New London, Conn.	53 21 N.	29 50 W.	July 9	10a, 9	July 9	29.67	S	SSW, 6	S	SSE, 8	S-SSW-SSE.
Lara, Am. S.S.	New York	San Juan	31 54 N.	70 17 W.	July 13	8p, 13	July 14	29.70	S	S, 8	WSW	SW, 8	S-SW.
Borinquen, Am. S.S.	do	do	32 45 N.	70 55 W.	do	11p, 13	July 13	29.38	SE	NE, 10	NW	NE, 10	SE-NE-NW
Skagerrak, Ger. M.S.	Port Arthur	Manchester	39 40 N.	59 53 W.	July 15	10a, 15	July 15	28.94	SE	S, 12	W	S, 12	SE-S-WNW.
City of Hamburg, Am. S.S.	Havre	Norfolk	41 12 N.	57 00 W.	do	2p, 15	do	29.45	S	S, 10	WSW	SSW, 11	SSE-SSW-WSW.
Paris, Fr. S.S.	do	New York	42 40 N.	54 09 W.	do	11p, 15	July 16	29.64	S	SSW, 10	W	SW, 11	S-SSW-WSW.
Lekhaven, Du. S.S.	Antwerp	Norfolk	43 50 N.	53 15 W.	do	2a, 16	do	29.60	SSW	SW, 8	W	WSW, 9	SSW-SW-W.
Veendam, Du. S.S.	Rotterdam	New York	[1] 50 20 N.	14 50 W.	July 20	Noon, 20	July 20	29.37	N	N, 8	N	N, 8	WNW-N.
Seatrain New York, Am. S.S.	Habana	New Orleans	27 00 N.	86 42 W.	July 23	4p, 23	July 23	29.74	SW	SE, 3	SE	SE, 8	SW-SE.
Solana, Am. S.S.	Galveston	Baltimore	26 46 N.	88 30 W.	do	11p, 23	do	29.61	SE	S, 8	S	S, 8	N-SE-SSW.
W. S. Farish, Am. S.S.	Corpus Christi.	do	26 22 N.	92 04 W.	July 24	3p, 24	July 24	29.50	W	SW, 10	SSW	SW, 10	NW-SW-S.
Vacuum, Am. S.S.	Port Arthur	Philadelphia	29 18 N.	93 00 W.	do	4p, 24	do	29.68	NE	ESE, 8	SE	SE, 8	NE-E-SE.
NORTH PACIFIC OCEAN													
Californian, Am. M.S.	Los Angeles	Balboa	17 10 N.	101 57 W.	July 8	4p, July 8	July 9	29.76	ENE	ENE, 6	SE	E, 7	ENE-E.
Mobile City, Am. S.S.	Hilo, Hawaii	do	14 32 N.	105 25 W.	July 9	5a, 9	July 10	29.53	NNW	WSW, 8	SSW	WSW, 8	NNW-WSW-SW.
Taisei Maru, Jap. S.S.	Yokohama	Portland, Oreg.	46 00 N.	147 20 W.	July 14	11p, 14	July 14	[2] 29.44	WNW	WNW, 8	WNW	WNW, 8	None.
Tascalusa, Br. S.S.	Los Angeles	Manila	[1] 20 00 N.	127 35 E.	July 13	5a, 15	July 16	[2] 29.62	SW	W, 7	W	SW, 7	Do.
Manoeran, Du. M.S.	Manila	Los Angeles	20 16 N.	129 18 E.	July 14	3a, 16	July 15	29.31	WNW	WSW, 5	W	W, 8	W-WSW.
Do	do	do	25 49 N.	142 09 E.	July 18	2p, 18	July 18	29.57	SE	SE, 7	SSE	SE, 9	E-SE.
St. Therese, Am. M.S.	(3)	(3)	21 19 N.	106 37 W.	do	5a, 19	do	29.85	SE	E, 1	E	SE, 7	SE-E.
Norway Maru, Jap. S.S.	Victoria, B.C.	Yokohama	51 45 N.	166 10 W.	July 23	4p, 23	July 23	[2] 30.09	SSE	S, 7	SSE	SSE, 8	S-N.
Fernbrook, Nor. M.S.	Los Angeles	do	44 51 N.	175 36 E.	July 27	Noon, 27	July 27	29.66	SW	SW, 8	SW	SW, 8	SW-W.
Do	do	do	41 13 N.	156 45 E.	July 30	4p, 30	July 30	29.66	WSW	WSW, 8	W	WSW, 9	WSW-W.

[1] Position approximate. [2] Barometer uncorrected. [3] At fishing banks, out of San Diego.

NORTH PACIFIC OCEAN, JULY 1934

By WILLIS E. HURD

Atmospheric pressure.—During July 1934, the greater part of the North Pacific Ocean, except the Tropics and far eastern waters, was under the influence of anticyclonic weather conditions. The Aleutian LOW, so far as the average pressure for the month is concerned, was nonexistent in southern Alaskan waters, and no disturbances of importance developed over the northern part of the ocean. Pressure at St. Paul, in the Bering Sea, was 0.17 inch above the July normal, but at Juneau it was 0.06 below. These were the extreme July departures for the ocean as noted on table 1.

The average barometer (29.81 inches) at Naha, in the Nansei group, was 0.09 inch above the normal, despite the fact that abnormally low pressures prevailed there from the 13th to 19th, owing to the near proximity of a tropical cyclone.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level, North Pacific Ocean, July 1934, at selected stations*

Stations	Average pressure	Departure from normal	Highest	Date	Lowest	Date
	Inches	Inch	Inches		Inches	
Point Barrow	29.89	−0.03	30.14	2, 3, 25	29.40	7
Dutch Harbor	30.03	+.09	30.40	24	29.62	18
St. Paul	29.97	+.17	30.42	24	29.44	19
Kodiak	30.04	+.10	30.50	1	29.62	15, 16
Juneau	29.99	−.06	30.39	2	29.35	16
Tatoosh Island	30.09	+.04	30.36	10	29.69	15
San Francisco	29.97	+.02	30.10	29	29.84	12
Mazatlan	29.87	+.02	29.96	3	29.78	24
Honolulu	30.03	+.01	30.14	29	29.92	26
Midway Island	30.09	−.02	30.22	29, 30	29.94	12
Guam	29.83	−.01	29.90	22, 23	29.70	14
Manila	29.76	−.04	29.92	30	29.52	18
Naha	29.81	+.09	30.02	30	29.40	15
Chichishima	29.91	+.06	30.04	22, 29, 30	29.70	11, 16
Nemuro	29.83	----------	30.18	31	29.60	10

NOTE.—Data based on 1 daily observation only, except those for Juneau, Tatoosh Island, San Francisco, and Honolulu, which are based on 2 observations. Departures are computed from best available normals related to time of observation.

Cyclones and gales.—The generally quiet weather prevalent during June over the North Pacific Ocean continued through July, except that the eastern and western tropics showed somewhat more evidence of disturbed conditions.

In the extra-tropical area the greater number of depressions ran in high latitudes, except for a few comparatively shallow cyclones which proceeded eastward from Japanese waters. Of these LOWS, only two caused recorded gales, one on the 19th of force 8 and the other on the 30th of force 9. Both occurred between 40° and 45° N., 155° and 170° E. Fresh gales, in addition, were experienced on the 23d, south of Dutch Harbor, and on the 14th, near 46° N., 147° W. That of the 14th was due to a depression, central near 50° N., 135° W., which developed on the 13th and withdrew northward on the 15th.

In Asiatic tropical waters a cyclone appeared at some distance southeast of the Nansei Islands on the 13th. It moved slowly westward until the 18th when, near the northern extremity of the island of Taiwan, it had a barometric depth of 29 inches. Thence it recurved northward and died out on the 23d in the Japan Sea. The cyclone was characterized as a typhoon on the Japanese weather maps. A ship report on the 15th, near 20° N., 129° E., recorded a maximum wind force of 8, and a report from Ishigashima Island on the 17th gave a similar velocity. These are the highest forces for the cyclone shown by our present records.

From the 17th to 19th a small depression moved in the neighborhood of the Ogasawara Islands, and in this disturbed area a southeast gale of force 9, lowest barometer 29.57, was reported on the 18th.

In Mexican west coast waters two disturbances, of which we have only brief record, likewise occurred. The first was noted southwest of Acapulco on the 8th and 9th, with a wind force of 7 from the east. Farther westward, on the 9th, the American S.S. *Mobile City* encoun-

tered a westerly gale of force 8, lowest pressure 29.53 inches, near 14½° N., 105½° W.

In the second instance the American motorboat *St. Therese*, while north of Cape Corrientes on the 18th, experienced a southeast wind of force 7. Mr. Eichler, the observing officer on board, made the following informational comment:

July 18. Had reports from M.S. *San Lucas*, M.S. *Atlantic*, and M.S. *San Salvador*, in vicinity of the Revillagigedo Islands, that wind of hurricane velocity was blowing, accompanied by fog and rain, with an occasional shift of wind.

Fog.—Following upon the unusual and almost complete absence of fog from our west coast waters in June, there was a heavy recurrence of it along the Peninsula of California in July, where it was observed on 10 days. Between San Diego and San Francisco it was experienced on 5 days. The occurrence of fog on the northern steamer routes this month was the maximum thus far this year for that region. Along most of the Great Circle route between the 140th meridian of west longitude and Japan it was observed on 10 percent to 30 percent or more of the days, with the area of greatest frequency south of the Aleutian Islands. One casualty due to dense fog was the sinking of the seiner *Umatilla* by the U.S.S. *Arizona* off Tatoosh Light on July 26. Of nine men aboard the seiner, two were lost as a result of the accident.

TYPHOON AND DEPRESSIONS IN THE FAR EAST JULY 1934

BERNARD F. DOUCETTE, S. J.

During the month of July 1934, 1 typhoon and 4 depressions influenced the weather conditions of the Far East.

The typhoon appeared on the weather map July 15, 6 a.m., near longitude 129° E., latitude 21° N.; observations from S.S. *Manoeran* and S.S. *Tuscalusa* indicated its existence. It moved northwest, changing to west-northwest July 16 and approaching Formosa; July 19, 6 a.m., found the typhoon located over northern Formosa. It then changed its course to the northwest, crossed the Formosa Channel, and entered China, gradually recurving to the north-northeast, and leaving China about 100 miles north of Shanghai. After crossing the Yellow Sea and Korea (July 23), it filled up in the Sea of Japan.

On July 14, a definite southwest current of air began to move over the Philippines, continuing until the typhoon entered China (July 21). Very little precipitation was connected with this southwest air at first. On the evening of July 16, however, heavy precipitation began over the northern part of the Archipelago. At Manila, this was preceded by thunder and lightning to the northwest. For 3 days these heavy rains continued, causing considerable damage to crops and roads. The Ilocos Express of the Manila Railroad Co. was derailed at a washout along the tracks. Baguio was isolated for about 2 days, due to landslides along the mountain roads leading to the city. Four deaths due to drowning in swollen rivers were reported later in the month. Such, in brief, was the damage caused by a typhoon about 500 miles north-northeast of Manila.

There is good evidence that a northerly current of air existed aloft while these heavy rains prevailed. Surface data from stations along the Formosa Channel on the afternoon of July 16, as well as upper air data given by Hong Kong, show the beginning of this northerly current of air, which continued for the next few days. It seems that interaction between the southwest current of air at the surface and the northerly air aloft caused the heavy precipitation; it is certain that the heavy rains prevailed while Hong Kong had these northerly currents. It is difficult to determine the origin of this air. Surface data from the few interior stations of China show northerly winds; yet it is possible that these upper currents traveled around the periphery of the typhoon and had their origin over southern maritime regions.

On the afternoon of July 19, a front existed in the Formosa Channel. The typhoon was about 100 miles to the east at the time, while the S.S. *Empress of Japan* and the S.S. *Pres. Van Buren* passed from a region of north and north-northeast winds to west-southwest and southwest winds, accompanied by lightning and thunder. The S.S. *Tjisdane* anchored at Beal Harbor (longitude 122°20′ E., latitude 30°29′ N.) from July 20, midnight, until 7 p.m. July 21; during this period the typhoon passed about 150 miles to the west. Winds were mainly from the southeast, force 7 the highest velocity, and 748.4 millimeters (not corrected for gravity) the lowest pressure, recorded (6 p.m. July 20 and 4 a.m. July 21). There were no discontinuities in wind direction at this location as the typhoon passed to the west.

A weak depression, small in area, formed in the Pacific the night of June 30. The next morning, its center was near longitude 123° E., latitude 15° N., from which position it moved westward, crossing Luzon a short distance north of Manila and then slowly moving across the China Sea into Indo China.

A low-pressure area was located July 6 near longitude 131° E., latitude 15° N. It moved northwest, at first rapidly, and then slowly, recurving July 10 and 11 to the northeast near longitude 125° E., latitude 19° N. July 12 found it located at longitude 131° E., latitude 24° N., after which it changed its course more to the north; July 15 was the last day it appeared on the weather map (longitude 136° E., latitude 27° N.).

On July 10, 6 a.m., a depression appeared in the Balingtang Channel, (longitude 120° E., latitude 20° N.) and moved northwest, recurving to the northeast July 12 and 13 south of Macao; it then traveled for 2 days, changing its direction to the east on July 14, and to the north on the 15th near longitude 130° E., latitude 25° N.

On July 29, a depression appeared on the weather map, located northwest of the Island of Hainan. It moved into Indo China the next day, direction northwest.

CLIMATOLOGICAL TABLES

CONDENSED CLIMATOLOGICAL SUMMARY

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, July 1934

[For description of tables and charts, see Review, January, p. 37]

Section	Temperature								Precipitation					
	Section average	Departure from the normal	Monthly extremes						Section average	Departure from the normal	Greatest monthly		Least monthly	
			Station	Highest	Date	Station	Lowest	Date			Station	Amount	Station	Amount
	°F.	°F.		°F.			°F		In.	In.		In.		In.
Alabama	81.8	+1.5	Decatur	106	23	St. Bernard	60	5	6.55	+1.12	Lock No. 2	11.90	Tuscumbia	1.86
Arizona	83.9	+2.1	Quartzsite	124	11	2 stations	39	[1] 5	1.25	−.87	Wikieup	5.63	2 stations	.00
Arkansas	85.5	+5.1	2 stations	112	[1] 20	Dutton	57	7	1.66	−2.15	Marked Tree	5.71	Gravette	.04
California	72.9	−.8	Greenland Ranch	125	[1] 12	Portola	26	[1] 5	.05	−.02	Kingston	1.43	202 stations	.00
Colorado	71.8	+4.9	Las Animas	112	13	Pearl	23	18	1.11	−1.12	Leadville	7.67	Paonia	T
Florida	81.6	+.3	2 stations	99	[1] 16	La Belle	61	12	7.30	+.11	Perry	12.50	Fort Pierce	2.89
Georgia	82.4	+2.3	do	105	[1] 17	Dahlonega	56	16	4.69	−1.00	Moultrie	8.02	Dover	2.12
Idaho	69.9	+1.9	Orofino	118	28	Bostetter Ranger Station.	24	9	.23	−.39	Deadwood	2.68	2 stations	.00
Illinois	81.5	+5.2	Sparta	114	24	Morris	44	8	3.27	−.02	Olney	8.39	White Hall	.04
Indiana	80.6	+5.1	Collegeville	113	21	Fowler	45	31	2.42	−.92	New Harmony	5.41	Vevay	.35
Iowa	79.7	+5.4	Keokuk No. 2	118	20	Thurman	40	7	3.86	+.13	Olin	9.88	Centerville	.06
Kansas	87.2	+8.3	Lincoln	119	13	Oketo	47	7	1.13	−2.17	Pleasanton	3.29	Smith Center	.00
Kentucky	81.2	+4.1	Williamstown	110	[1] 22	Farmers	57	16	4.36	+.22	Dix Dam	8.62	Marion	1.12
Louisiana	82.8	+1.0	Minden	109	18	Arcadia	60	8	5.00	−1.19	Baton Rouge	11.02	Arcadia	.34
Maryland-Delaware	78.4	+3.2	Hancock, Md	107	25	Grantsville, Md	42	18	3.41	−.83	Dover, Del	10.78	Boyds, Md	.52
Michigan	71.2	+2.5	4 stations	108	[1] 21	Dukes	31	4	1.46	−1.30	Yale	4.95	Muskegon	.23
Minnesota	71.1	+1.4	Milan	113	21	3 stations	34	7	2.24	−1.11	Grand Meadow	5.45	Beardsley	.39
Mississippi	83.0	+1.9	Hernando	110	23	Utica	64	6	4.76	−.31	Shubuta	15.44	Austin	.41
Missouri	86.2	+8.4	Louisiana	117	18	2 stations	48	7	1.11	−2.67	Clinton	5.22	Palmyra	.00
Montana	69.4	+2.8	Brunelda	112	20	3 stations	28	[1] 6	.74	−.73	Red Lodge (near)	2.37	Heron	.04
Nebraska	82.5	+7.8	Geneva	118	15	Weeping Water	40	6	1.11	−2.23	Stanton	4.11	Hebron	T
Nevada	74.5	+2.2	Logandale	118	[1] 12	Canyon Creek Ranch.	27	8	.20	−.17	Boulder City	1.18	14 stations	.00
New England	70.4	+1.4	4 stations	98	[1] 3	Somerset, Vt	35	23	3.17	−.54	Gardiner, Maine	6.65	Provincetown, Mass	.24
New Jersey	75.8	+2.1	2 stations	100	[1] 21	Runyon	43	18	3.65	−1.14	Runyon	6.89	Lakewood	1.85
New Mexico	75.3	+3.0	Oro Grande	116	14	Selsor Ranch	26	6	1.34	−1.25	Cloudcroft	4.01	2 stations	.00
New York	71.6	+2.0	Angelica	102	6	Indian Lake	34	[1] 5	2.88	−1.01	2 stations	8.13	Lowville	.68
North Carolina	79.1	+2.2	3 stations	102	21	2 stations	50	[1] 2	6.63	+.85	Goldsboro	14.51	Caroleen	1.25
North Dakota	71.8	+3.4	do	112	[1] 20	Powers Lake	29	6	1.22	−1.20	Cavalier	3.33	Alpha	.02
Ohio	78.6	+5.0	Gallipolis (near)	113	21	2 stations	46	18	2.64	−1.13	Dam No. 28	6.89	Kenton (near)	.46
Oklahoma	88.0	+6.5	Vinita	116	24	Seminole	57	7	.64	−2.40	Tuscahoma	3.40	4 stations	.00
Oregon	66.7	+.3	4 stations	110	[1] 27	Austin	20	11	.15	−.26	Seaside	1.80	14 stations	.00
Pennsylvania	75.5	+3.5	Hyndman	107	26	4 stations	40	[1] 16	4.01	−.28	Ephrata	7.83	Greenville	1.16
South Carolina	82.2	+2.4	Trenton	106	20	Caesars Head	60	[1] 7	4.46	−1.34	Ellenton	9.53	Garnett	1.43
South Dakota	77.7	+5.1	2 stations	118	[1] 20	Redig	35	6	1.88	−.73	Sioux Falls	6.24	Harveys Ranch	.30
Tennessee	81.4	+3.8	3 stations	109	24	Elkmont	56	[1] 1	4.42	−.01	Erwin	10.66	Newbern	.62
Texas	85.5	+2.5	do	113	[1] 24	Spearman	55	8	1.96	−.64	Matagorda	10.34	9 stations	.00
Utah	74.6	+2.7	St. George	112	[1] 27	Coalville	25	8	.65	−.24	Milford	2.62	2 stations	T
Virginia	78.8	+3.4	Lincoln	105	21	Burkes Garden	52	18	5.07	+.59	Diamond Springs	12.14	Riverton	1.08
Washington	65.6	−.4	Alpowa Ranch	115	27	Bumping Lake	29	17	.72	+.07	Wishkah Headworks.	6.11	10 stations	.00
West Virginia	77.5	+4.4	Martinsburg	107	25	Bayard	40	18	4.56	−.01	Kayford	12.96	Upper Tract	1.96
Wisconsin	71.6	+1.7	Weyerhauser	109	23	Prentice	32	[1] 7	2.85	−.74	La Crosse	8.27	Sheboygan	.46
Wyoming	68.8	+3.3	Dull Center (near)	111	15	South Pass City	24	[1] 1	1.10	−.22	Crandall Creek (near).	3.33	West Yellowstone	.17
Alaska (June)	52.6	−1.9	Nenana	98	28	Barrow	18	13	1.59	−.38	Ketchikan	11.25	Barrow	T
Hawaii	75.4	+1.1	Waiawa	98	20	Kanalohuluhulu	48	[1] 2	5.50	−.70	Puukukui (upper)	23.00	4 stations	.00
Puerto Rico	78.2	−.2	San German	96	11	Guineo Reservoir	52	5	6.10	−.65	Mayaguez	14.15	Mona Island	.30

[1] Other dates also.

TABLE 1.—*Climatological data for Weather Bureau stations, July 1934*

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	Pct.	In.	In.		Miles								0-10	In.	In.
New England							70.7	+1.8										75	2.27	-1.2										5.1		
Eastport	76	67	85	29.85	29.93	0.00	60.8	+0.4	79	5	70	48	1	52	25	57	54	83	3.50	+0.4	10	5,770	sw.	24	nw.	3	7	13	11	5.8	0.0	0.0
Greenville, Maine	1,070	6	40	28.79	29.95		64.0		83	15	75	44	10	54	36				3.96		14	3,922	nw.	24		1	9	10	12		.0	.0
Portland, Maine	103	82	117	29.82	29.94	-.01	69.6	+1.5	96	7	78	56	2	62	28	62	57	69	3.35	+.1	10	5,905	s.	28	nw.	3	20	6	5	3.5	.0	.0
Concord	289	60					70.8	+2.3	92	3	83	47	18	58					4.43	+.9	5		nw.				14	9	8		.0	.0
Burlington	403	11	48	29.51	29.93	-.01	70.1	-.2	90	19	81	48	23	59	32				2.40	-1.1	9	6,214	s.	25	se.	12	7	18	6	5.1	.0	.0
Northfield	876	12	60	29.02	29.94	.00	67.0	+1.1	89	3	81	41	23	53	40	62	59	74	1.83	-1.8	9	5,147	s.	21	sw.	3	7	19	5	5.3	.0	.0
Boston	124	336	360	29.80	29.94	-.02	73.2	+1.5	93	7	82	57	23	65	24	66	61	68	1.25	-2.2	7	8,991	sw.	39	nw.	3	7	18	6	5.4	.0	.0
Nantucket	12	14	90	29.94	29.95	-.03	70.2	+2.4	86	16	77	52	12	64	22	65	63	84	.86	-2.0	3	9,451	sw.	30	sw.	7	12	9	10	5.3	.0	.0
Block Island	26	11	46	29.93	29.96	-.01	71.0	+2.6	83	19	77	57	11	65	19	67	65	85	.52	-2.6	6	9,070	sw.	25	sw.	7	8	17	6	5.2	.0	.0
Providence	160	215	251	29.78	29.95	-.02	74.9	+1.5	96	7	84	55	11	65	26	66	62	66	.82	-2.4	5	7,012	nw.	49	nw.	7	12	12	7	4.4	.0	.0
Hartford	159	70	104		29.95	-.02	75.1	+3.5	95	3	85	55	11	65	30				2.97	-1.4	7	4,992	s.				10	9	12		.0	.0
New Haven	106	74	153	29.85	29.96	-.01	74.8	+3.0	96	7	83	57	11	66	25	67	63	70	3.04	-1.3	6	5,905	s.	31	nw.	3	9	12	10	5.7	.0	.0
Middle Atlantic States							77.8	+2.7										72	4.03	-0.3										6.1		
Albany	97	107	115	29.84	29.94	-.02	74.4	+1.8	94	3	85	54	23	64	32	65	61	66	2.98	-.4	8	5,080	s.	21	se.	3	10	10	11	5.3	.0	.0
Binghamton	871	60	68	29.06	29.97	.00	72.4	+2.4	94	20	85	49	17	60	40				2.74	-1.0	11	3,703	nw.	22	nw.	3	7	7	17	6.6	.0	.0
New York	314	415	454	29.63	29.95	-.03	76.2	+2.4	94	21	84	62	12	68	24	68	64	71	5.67	+1.4	9	8,656	s.	58	nw.	3	9	12	10	5.4	.0	.0
Bellefonte	1,050	5	42	28.88	29.96		73.0		100	25	86	48	18	60	44	65	61	69	5.83		12		sw.				9	12	10	5.7	.0	.0
Harrisburg	374	94	104	29.55	29.94	-.04	78.1	+3.3	97	21	88	59	18	68	29	68	64	67	2.68	-1.2	11	4,553	w.	24	ne.	21	10	12	9	5.4	.0	.0
Philadelphia	114	123	367	29.85	29.97	-.01	79.3	+3.1	98	21	88	64	11	71	25	69	65	67	2.18	-2.0	11	7,915	sw.	38	n.	15	7	14	10	5.4	.0	.0
Reading	323	283	306	29.61	29.95		76.9	+1.4	97	21	86	56	11	68	30	69	65	72	6.53	+2.3	9	6,392	s.	57	n.	15	11	15	5	5.1	.0	.0
Scranton	805	72	104	29.12	29.96	-.02	74.4	+2.7	95	6	86	51	18	63	36	66	61	68	6.74	+2.7	12	4,328	n.	33	nw.	3	7	19	5	5.1	.0	.0
Atlantic City	52	37	172	29.91	29.96	-.02	75.7	+3.6	91	16	81	64	17	70	22	70	68	81	2.09	-1.8	9	9,825	s.	33	w.	16	3	15	13	6.5	.0	.0
Sandy Hook	22	10	57	29.94	29.96		75.7		94	7	83	63	12	69	26	69	66	76	4.74	-.4	10	7,940	s.	43	s.	20	12	8	11	4.9	.0	.0
Trenton	190	88	106	29.76	29.95		76.6	+2.1	96	2	86	57	12	67	29	68	64	69	2.90	-1.0	13	6,131	s.	46	nw.	15	10	11	10	5.3	.0	.0
Baltimore	123	100	215	29.83	29.95	-.03	81.4	+4.2	102	21	90	64	11	73	23	71	67	67	2.24	-2.4	7	6,709	s.	29	ne.	25	13	13	5	4.8	.0	.0
Washington	112	62	85	29.84	29.95	-.05	80.8	+4.0	100	21	90	62	11	71	28	71	67	68	2.88	-1.8	7	4,341	sw.	30	nw.	25	11	14	6	4.6	.0	.0
Cape Henry	18	8	54	29.95	29.97		79.5	+2.0	95	7	86	69	10	72	24	74	72	81	6.18	+.8	14	7,164	sw.	30	n.	25	4	21	6	5.6	.0	.0
Lynchburg	686	5	188	29.26	29.98	-.03	81.8	+4.3	104	26	94	64	3	69	35				3.04	-1.2	12		sw.				1	28	2		.0	.0
Norfolk	91	170	205	29.89	29.98	-.02	79.8	+1.1	96	16	88	67	8	72	27	74	72	81	8.19	+2.4	17	7,845	s.	42	sw.	8	4	9	18	7.1	.0	.0
Richmond	144	11	52	29.83	29.97	-.04	80.6	+2.1	100	21	90	63	11	71	30	73	71	81	3.22	-1.5	12	5,211	sw.	32	ne.	20	6	21	4	5.3	.0	.0
Wytheville	2,304	49	55		29.96	-.05	75.9	+3.3	95	23	86	61	3	66	29			78	3.51	-.5	16	4,224	w.	21	n.	26	6	19	6		.0	.0
South Atlantic States							81.6	+2.2										80	4.09	-1.7										6.1		
Asheville	2,253	89	104	27.74	30.01	-.01	76.6	+4.9	95	23	88	64	11	66	28	68	67	82	4.50	+.2	21	4,300	nw.	30	n.	25	6	8	17	6.6	.0	.0
Charlotte	779	244	267	29.19	30.00	-.02	79.9	+1.5	96	21	89	67	12	71	27	72	69	78	3.07	-2.0	17	7,011	sw.	45	ne.	21	3	17	11	6.3	.0	.0
Greensboro	886	6	56	29.07	30.00		79.5		98	21	89	64	8	70	29	73	71	85	7.14		13	4,950	sw.	49	nw.	26	3	14	14	7.0	.0	.0
Hatteras	11	5	50	29.99	30.00	-.01	80.5	+2.3	90	16	85	72	12	76	15	74	76	82	6.00	+.5	10	8,142	sw.	30	nw.	20	11	11	9	5.0	.0	.0
Raleigh	376	103	146	29.59	29.97	-.05	80.8	+2.0	98	16	90	68	9	72	27	74	72	81	6.37	+1.0	11	5,640	sw.	35	ne.	20	2	15	14	6.8	.0	.0
Wilmington	72	73	107	29.94	30.01	.00	81.2	+2.1	97	17	88	69	21	74	24	76	74	82	3.09	-4.0	13	6,752	sw.	30	s.	30	5	22	4	5.5	.0	.0
Charleston	48	11	92	29.96	30.01	-.02	83.9	+2.5	98	20	91	73	12	77	20	78	76	82	2.35	-4.5	9	7,375	sw.	27	e.	22	2	22	7	6.2	.0	.0
Columbia, S.C	351	41	57	29.63	30.00	-.02	82.7	+1.8	101	21	93	69	6	73	27	74	72	77	4.27	-1.1	14	4,952	sw.	24	sw.	27	6	22	3	5.2	.0	.0
Augusta	182	62	77	29.80	29.99	-.03	83.6	+2.3	101	25	94	69	29	74	26	75	72	75	2.16	-3.2	13	4,369	nw.	21	w.	29	6	19	6	5.6	.0	.0
Savannah	65	73	152	29.94	30.01	-.02	83.8	+2.3	101	14	93	70	3	74	28	75	73	78	4.06	-2.6	11	7,268	sw.	35	se.	19	9	17	5	5.0	.0	.0
Jacksonville	43	86	110	29.98	30.04	+.01	82.5	+.4	96	14	91	65	14	74	31	74	72	78	5.07	-1.6	15	5,577	sw.	32	ne.	14	7	23	1	4.6	.0	.0
Florida Peninsula							82.4	+0.5										77	6.67	+1.2										5.7		
Key West	22	10	64	30.00	30.02	-.01	82.9	-.6	91	31	88	70	7	77	16	77	74	75	5.03	+1.8	12	6,027	se.	27	sw.	23	9	14	8	5.4	.0	.0
Miami	25	124	168	30.02	30.05	+.01	82.2	+1.2	90	15	88	69	12	77	21	75	73	76	8.18	+2.8	19	6,274	se.	24	ne.	12	3	16	12	6.7	.0	.0
Tampa	35	88	197	30.00	30.03	-.01	82.2	+1.0	94	17	90	67	25	74	23	75	73	81	6.81	-1.1	20	6,639	e.	38	e.	25	6	20	5	5.1	.0	.0
Titusville	43	5	36	29.99	30.04		81.6		96	16	91	67	3	72	25				4.04		11		s.				12	8	11		.0	.0
East Gulf States							81.7	+1.0										78	6.23	+0.5										5.7		
Atlanta	1,173	128	135	28.81	30.02	.00	80.0	+1.9	96	17	89	66	19	71	26	71	69	76	5.49	+.8	14	5,553	nw.	34	s.	19	5	13	13	6.5	.0	.0
Macon	370	79	87	29.62	30.01	-.01	83.0	+1.8	101	25	93	68	31	73	27	73	71	74	3.84	-.9	11	4,446	s.	24	nw.	12	5	23	3	5.3	.0	.0
Thomasville	273	49	58	29.75	30.04	+.01	81.2	-.6	96	21	91	67	26	71	26	75	73	82	7.70	+1.0	20		sw.				5	15	11		.0	.0
Apalachicola	35	11	51	29.98	30.02		81.4		94	21	88	70	17	75	21	76			9.21	+1.5	20		sw.				3	19	9		.0	.0
Pensacola	56	149	185	29.97	30.03	+.02	80.9	-.1	95	23	87	69	6	75	20	75	73	80	3.79	-3.0	13	8,710	sw.	39	s.	6	11	14	6	4.9	.0	.0
Anniston	741	9					80.3	+2.4	100	23	91	62	26	70	29				5.57	+.4	12		nw.				7	18	6		.0	.0
Birmingham	700	11	48	29.27	30.01	.00	81.0	+.8	100	23	90	68	31	72	26	73	71	81	5.75	+.6	14	3,926	s.	21	ne.	25	7	14	10	5.8	.0	.0
Mobile	57	125	161	29.95	30.01	.00	82.2	+.8	97	21	90	70	3	75	21	75	73	80	6.06	-.8	14	6,405	sw.	29	e.	10	4	15	12	6.3	.0	.0
Montgomery	218	92	105	29.78	30.02	.00	82.6	+.9	98	22	92	69	31	74	25	74	72	78	4.10	-.8	16	4,560	sw.	21	w.	2	10	8	13	5.8	.0	.0
Meridian	375	67	92	29.62	30.00	-.02	81.8	+1.4	99	23	91	69	8	72	26	74	72	80	11.57	+6.7	14	3,883	sw.	27	ne.	25	11	12	8	5.0	.0	.0
Vicksburg	247	65	73	29.75	30.00	.00	82.5	+1.2	96	17	91	69	19	74	23	74	72	77	3.91	-.6	9	4,768	s.	29	s.	19	12	11	8	5.2	.0	.0
New Orleans	53	76	84	29.96	30.01	+.01	82.8	+.4	98	23	89	72	30	76	20	76	73	77	7.72	+1.4	17	4,811	sw.	26	e.	24	5	17	9	6.2	.0	.0
West Gulf States							85.0	+2.4										67	2.41	-0.7										3.9		
Shreveport	249	92	227	29.71	29.97	-.01	86.0	+2.8	103	17	97	69	6	75	29	74	69	63	.41	-3.2	3	7,105	sw.	33	ne.	27	17	12	2	3.5	.0	.0
Bentonville	1,303	11	44	28.60	29.92	-.05	84.6	+6.1	108	24	99	62	29	70	35				1.93		2	4,046	sw.	22	sw.	14	12	17	2		.0	.0
Fort Smith	457	79	94	29.45	29.92	-.05	89.2	+7.7	107	24	102	71	14	76	33	71	63	48	.15	-3.2	1	5,209	e.	30	se.	15	17	13	1	3.7	.0	.0
Little Rock	357	94	102	29.59	29.96	-.03	85.0	+4.1	103	23	96	67	6	74	29	73	68	63	2.28	-1.2	4	5,505	sw.	34	n.	16	19	9	3	3.4	.0	.0
Austin	605	136	148	29.32	29.94		85.7	+1.7	105	24	97	70	19	75	29	72	67	62	.79	-1.5	4	6,813	s.	27	n.	6	19	8	4	3.2	.0	.0
Brownsville	57	88	96	29.87	29.93		82.3	-1.3	99	24	89	72	12	76	26	75	74	83	3.64	+1.7	12	7,841	se.	37	nw.	24	13	11	7	4.9	.0	.0
Corpus Christi	20	11	78	29.95	29.97	+.01	82.6	-.1	105	24	89	72	30	76	29	77	75	82	5.46	+3.9	8	8,805	s.	47	s.	25	16	7	8	4.6	.0	.0
Dallas	512	220	227	29.40	29.93		87.3		103	24	97	73	7	78	24	71	63	50	.01	-2.8	1	7,936	s.	33	ne.	2	22	8	1	2.6	.0	.0
Fort Worth	670	106	114	29.25	29.95	-.01	88.2	+4.6	105	24	99	72	7	77	28				.08	-2.5	2	7,337	s.	32	sw.	22	23	7	1	1.6	.0	.0
Galveston	54	106	114	29.93	29.99	+.01	82.3	-1.1	93	27	87	71	24	78	21	76	74	79	4.55	+.8	12	8,398	s.	46	se.	25	16	10	5	4.5	.0	.0
Houston	138	292	314	29.84	29.98		83.4	-.3	100	18	92	68	7	74	26				4.39	+.4	10	8,360	s.	48	se.	25	11	13	7	4.7	.0	.0
Palestine	510	64	72	29.45	29.97	.00	85.6	+3.4	104	24	97	70	11	74	29	73	67	63	1.17	-1.5	3	5,934	s.	26	se.	27	18	12	1	3.2	.0	.0
Port Arthur	34	58	66	29.95	29.99		82.3		99	23	89	67	7	75	25	75	73	79	4.62	-2.3	13	6,303	s.	38	ne.	24	6	19	6	5.5	.0	.0
San Antonio	693	242	301	29.22	29.92	-.03	84.8	+1.0	104	24	96	69	26	74	29	72	67	66	3.83	+1.7	6	9,176	se.	43	ne.	25	9	17	5	4.9	.0	.0

TABLE 1.—*Climatological data for Weather Bureuu stations, January, 1934*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature: Departure from normal	Temperature: Maximum	Temperature: Date	Temperature: Mean maximum	Temperature: Minimum	Temperature: Date	Temperature: Mean minimum	Temperature: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01 or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	Pct.	In.	In.		Miles								0–10	In.	In.
Ohio Valley and Tennessee							**80.9**	**+4.3**										68	**3.15**	**−0.07**										**5.2**		
Chattanooga	762	71	214	29.21	30.00	−0.02	81.7	+3.3	104	23	92	68	10	72	30	73	71	75	6.46	+2.2	15	4,822	w.	32	ne.	15	7	17	7	5.5	0.0	0.0
Knoxville	995	66	84	28.97	30.00	−.02	81.2	+4.1	101	24	92	67	16	71	30	72	69	74	4.35	.0	12	4,012	sw.	27	ne.	15	13	12	6	4.7	.0	.0
Memphis	399	78	86	29.56	29.97	−.03	84.9	+4.2	104	23	94	67	6	76	23	74	70	66	.73	−2.4	4	4,997	sw.	28	nw.	6	10	14	7	4.9	.0	.0
Nashville	546	168	191	29.43	30.00	−.01	82.2	+3.1	104	24	92	67	9	72	30	73	70	73	3.85	.0	10	5,263	w.	30	n.	14	5	18	8	5.9	.0	.0
Lexington	989	5																														
Louisville	525	188	234	29.42	29.99	−.01	82.4	+3.8	105	23	92	64	8	73	26	72	68	67	2.10	−1.6	11	6,249	s.	32	s.	14	8	12	11	5.5	.0	.0
Evansville	431	76	116	29.51	29.97	−.03	83.1	+4.2	104	24	92	66	8	74	28	73	70	68	1.85	−1.6	8	5,283	s.	32	ne.	13	10	13	8	5.0	.0	.0
Indianapolis	822	194	230	29.11	29.97	−.02	81.6	+5.9	106	21	92	60	8	71	29	69	64	60	2.50	−.8	11	6,490	s.	32	w.	24	9	14	8	5.3	.0	.0
Terre Haute	575	96	129	29.35	29.95		82.0		104	24	92	60	8	71	27	70	66	63	4.58	+1.4	10	5,956	sw.	27	s.	13	13	12	6	4.5	.0	.0
Cincinnati	627	11	51	29.30	29.96	−.04	82.2	+7.1	108	21	94	59	8	70	33	70	65	62	2.44	−.9	10	4,558	sw.	21	sw.	26	10	12	9	5.4	.0	.0
Columbus	822	216	230	29.11	29.96	−.04	80.2	+5.3	106	21	91	62	31	69	31	69	63	63	2.94	−.6	9	6,432	ne.	51	nw.	3	7	22	2	5.1	.0	.0
Elkins	1,947	59	78	28.02	29.98	−.03	74.1	+3.8	96	26	86	51	18	62	38	67	64	78	2.97	−2.4	12	3,270	nw.	23	w.	7	9	12	10	5.6	.0	.0
Parkersburg	637	77	84	29.36	30.00	−.01	79.6	+4.2	103	21	91	58	19	68	37	70	67	72	2.93	−1.4	11	3,870	se.	26	nw.	30	10	16	5	4.9	.0	.0
Pittsburgh	842	353	410	29.09	29.97	−.03	77.6	+3.0	98	24	88	60	18	68	33	68	64	66	3.25	−.8	8	5,950	sw.	38	nw.	3	10	9	12	5.6	.0	.0
Lower Lake Region							**74.4**	**+3.0**										62	**2.06**	**−1.2**										**4.7**		
Buffalo	768	243	280	29.13	29.94	−.03	71.8	+2.0	88	10	80	54	9	64	27	64	59	65	1.07	−2.0	7	8,412	sw.	52	sw.	6	11	16	4	4.6	.0	.0
Canton	448	10	61	29.45	29.91		70.2	−.3	91	15	82	45	23	58	37				2.54	−1.0	9	5,098	sw.	22	sw.	6	13	11	7	4.5	.0	.0
Ithaca	863	77	100	29.07	29.95		72.6	+2.1	97	19	86	49	9	60	41	64	60	68	4.11	+.6	15	5,371	nw.	38	w.	3	11	8	12	5.5	.0	.0
Oswego	335	71	85	29.58	29.94	−.02	71.0	+.6	94	6	79	57	9	63	30	64	59	68	1.91	−1.0	9	5,933	w.	23	sw.	6	11	10	10	5.3	.0	.0
Rochester	523	86	102	29.40	29.96	−.01	73.0	+2.3	94	6	83	52	9	63	31	63	57	57	1.35	−1.6	9	5,484	nw.	18	w.	30	12	11	8	4.8	.0	.0
Syracuse	596	65	79	29.33	29.97	.00	73.7	+2.9	95	19	84	53	9	63	34				2.49	−1.2	12	4,786	s.	24	nw.	19	6	17	8	5.5	.0	.0
Erie	714	130	166	29.21	29.95	−.03	74.6	+3.6	95	6	83	58	18	66	30	66	61	64	1.90	−1.1	9	7,643	nw.	43	nw.	12	15	13	3	4.0	.0	.0
Cleveland	762	267	337	29.15	29.96	−.03	76.0	+4.6	99	24	84	60	7	68	31	65	60	61	2.70	−.8	8	8,143	n.	38	s.	6	13	14	4	4.3	.0	.0
Sandusky	629	5	67	29.30	29.96	−.03	77.8	+4.4	104	24	87	59	18	68	39				1.24	−2.2	8	5,755	ne.	31	nw.	13	9	16	6	4.9	.0	.0
Toledo	628	79	87	29.29	29.96	−.03	77.4	+4.2	103	24	87	55	8	68	31	66	60	58	1.64	−1.4	7	6,140	e.	25	nw.	6	18	9	4	3.4	.0	.0
Fort Wayne	857	69	84	29.05	29.95		79.4	+5.9	106	22	91	56	31	68	31	67	60	56	2.18	−1.4	4	5,600	sw.	32	nw.	13	11	15	5	4.8	.0	.0
Detroit	626	5	78	29.29	29.96	−.02	75.6	+3.5	105	24	87	53	8	64	36	65	59	60	1.64	−1.7	7	6,158	ne.	33	w.	6	12	12	7	4.6	.0	.0
Upper Lake Region							**69.5**	**+1.7**										68	**1.69**	**−1.4**										**4.7**		
Alpena	609	13	89	29.32	29.98	+.01	66.8	+.9	93	24	77	48	8	57	37	61	57	70	3.22	+.5	8	7,185	nw.	25	nw.	3	20	6	5	3.1	.0	.0
Escanaba	612	54	60	29.33	29.98	+.01	65.6	−.4	88	2	74	46	7	58	26	60	57	73	2.16	−1.2	9	6,622	s.	23	w.	15	7	16	8	4.9	.0	.0
Grand Rapids	707	70	244	29.20	29.95	−.03	76.8	+4.5	104	21	80	55	7	65	34	65	58	56	.40	−2.5	5	6,476	n.	34	sw.	6	11	13	7	4.7	.0	.0
Lansing	878	6	88	29.03	29.94		73.6	+2.7	102	24	86	52	8	61	36	65	60	64	2.14	−1.0	5	5,404	sw.	30	w.	6	10	12	9	5.0	.0	.0
Ludington	637	5	54	29.28	29.97		69.3	+3.1	93	22	79	45	29	60	32	62			.70	−2.3	5		n.				12	12	7		.0	.0
Marquette	734	77	111	29.18	29.98	+.02	63.8	−1.1	90	14	73	47	17	55	28	58	54	71	2.01	−1.1	11	5,928	s.	28	nw.	14	10	12	9	5.3	.0	.0
Sault Sainte Marie	614	11	52	29.30	29.98	+.01	63.4	−.4	90	19	75	42	4	52	38	57	53	73	2.54	−.4	13	5,361	nw.	23	sw.	2	15	12	4	3.8	.0	.0
Chicago	673	7	131	29.24	29.96	−.02	76.6	+4.1	105	24	85	57	8	68	30	67	62	66	.42	−2.9	8	6,268	ne.	21	s.	19	9	14	8	5.3	.0	.0
Green Bay	617	109	141	29.30	29.96	−.01	71.1	+1.1	95	23	81	52	30	62	31	63	59	67	2.34	−1.1	9	6,535	s.	29	nw.	6	9	9	13	5.6	.0	.0
Milwaukee	681	97	221	29.24	29.96	−.01	72.4	+2.3	105	24	80	55	8	65	29	64	60	68	1.10	−1.7	7	6,944	e.	29	n.	28	13	6	12	5.3	.0	.0
Duluth	1,133	5	47	28.75	29.94	−.01	65.4	+1.5	90	24	76	46	7	55	33	58	54	71	1.53	−2.2	6	8,052	ne.	32	ne.	21	15	15	1	4.1	.0	.0
North Dakota							**72.4**	**+3.8**										52	**1.05**	**−1.5**										**4.2**		
Moorhead, Minn	940	50	58	28.91	29.90	−.04	72.5	+4.4	106	22	85	46	7	60	42	61	53	55	.80	−2.6	9	6,345	s.	24	e.	9	12	14	5	4.4	.0	.0
Bismarck	1,674	8	57	28.15	29.90	−.03	74.2	+4.4	106	18	88	43	6	61	41	60	52	52	.98	−1.3	7	7,081	e.	30	e.	7	11	17	3	4.5	.0	.0
Devils Lake	1,478	11	44	28.38	29.92	−.01	70.5	+3.1	105	18	85	41	6	56	38	58	50	53	1.58	−1.0	8	7,034	se.	29	ne.	20	13	14	4	4.2	.0	.0
Grand Forks	833	12	67				71.1		105	18	86	42	6	57	39	60			.93		9		se.	30	nw.	2	7	20	4		.0	.0
Williston	1,878	41	48	27.95	29.88	−.04	72.2	+3.3	99	17	85	37	6	59	37	58	48	48	.83	−1.1	8	6,566	se.	33	se.	7	14	15	2	3.6	.0	.0
Upper Mississippi Valley							**80.4**	**+5.2**										60	**3.89**	**+0.4**										**4.5**		
Minneapolis	918	102	208	28.96	29.92		76.2	+3.9	105	21	87	53	7	66	34	64	56	55	1.40	−2.3	9	7,025	n.	30	se.	16	12	10	9	5.1	.0	.0
La Crosse	714	11	48	29.16	29.91	−.05	75.4	+2.6	102	22	86	50	7	64	29	67	63	71	8.27	+4.4	12	2,942	s.	23	nw.	5	12	10	9	4.7	.0	.0
Madison	974	70	78	28.92	29.94	−.03	75.3	+3.2	101	24	85	55	8	66	29	66	62	66	3.42	−.5	8	5,096	se.	21	sw.	5	14	11	6	4.5	.0	.0
Charles City	1,015	10	51	28.88	29.93	−.03	76.7	+4.4	101	23	88	48	7	66	31	67	62	64	3.91	+.1	13	4,801	se.	27	sw.	9	14	9	8	4.1	.0	.0
Davenport	606	66	161	29.29	29.94	−.03	80.6	+5.3	106	24	91	59	7	70	33	69	64	61	4.50	+1.2	16	6,098	sw.	32	nw.	12	13	6	12	5.2	.0	.0
Des Moines	861	5	99	29.02	29.90	−.06	82.6	+7.2	109	19	95	53	7	70	33	68	60	54	2.52	−1.0	8	6,893	n.	32	n.	15	15	9	7	4.1	.0	.0
Dubuque	700	60	79	29.20	29.93	−.04	77.5	+3.4	103	22	88	55	7	67	32	68	63	64	5.48	+1.5	13	3,984	s.	24	nw.	10	16	4	11	4.5	.0	.0
Keokuk	614	64	78	29.28	29.93	−.05	84.8	+7.9	110	20	96	61	30	73	35	70	61	51	.95	−2.5	4	5,591	e.	23	nw.	5	11	13	7	4.6	.0	.0
Cairo	358	87	93	29.58	29.95	−.05	83.5	+3.9	105	24	94	67	9	73	33	73	70	69	3.41	+.3	8	4,921	s.	35	e.	25	10	12	9	5.2	.0	.0
Peoria	609	11	45	29.30	29.96	−.02	81.0	+5.6	105	23	93	58	8	69	37	70	65	63	5.44	+1.9	11	4,057	s.	18	n.	13	17	10	4	3.7	.0	.0
Springfield, Ill	636	5	191	29.27	29.93	−.05	83.4	+6.9	107	24	95	61	8	72	33	70	64	57	6.11	+3.2	9	7,466	s.	38	n.	13	12	12	7	4.6	.0	.0
St. Louis	568	265	303	29.34	29.93	−.06	87.2	+8.6	110	24	98	68	7	76	27	71	64	51	1.22	−1.8	4	7,984	sw.	31	sw.	31	16	12	3	3.3	.0	.0
Missouri Valley							**84.5**	**+8.4**										47	**1.63**	**−2.0**										**2.8**		
Columbia, Mo	784	6	84	29.12	29.92	−.06	86.8	+9.9	111	25	100	59	7	74	37				.67	−2.8	4	5,504	sw.	19	w.	13	17	14	0	3.2	.0	.0
Kansas City	750	32	45	29.11	29.88	−.03	88.4	+10.3	110	24	102	56	7	75	40	69	59	43	2.26	−1.9	7	7,309	sw.	43	nw.	13	21	9	1	2.9	.0	.0
St. Joseph	967	11	49	28.88	29.87		87.3		108	20	100	54	7	74	33	68	58	42	1.05	−2.6	5	5,878	sw.	32	se.	13	22	8	1	2.1	.0	.0
Springfield, Mo	1,324	98	104	28.58	29.94	−.04	85.4	+8.6	106	24	97	61	7	74	33	69	60	48	.89	−3.3	6	6,473	s.	30	se.	14	27	4	0	1.5	.0	.0
Iola	984	11	50	28.90	29.91	−.06	85.8	+7.6	107	24	100	57	7	71	38				1.81	−1.9	4		s.				22	7	2		.0	.0
Topeka	987	65	87				88.1	+10.3	111	15	102	57	7	74	38				2.87	−1.4	5	6,907	s.	31	n.	13	21	8	2	2.7	.0	.0
Lincoln	1,189	11	81	28.63	29.85	−.10	86.6	+10.1	112	15	100	49	7	73	37	67	56	42	.40	−3.4	7	7,531	s.	53	nw.	5	17	11	3	3.2	.0	.0
Omaha	1,105	170	200	28.74	29.87	−.08	85.4	+8.7	110	20	97	53	7	74	32	67	57	44	.52	−3.0	4	8,266	s.	34	n.	9	19	8	4	3.0	.0	.0
Valentine	2,598	47	54	27.23	29.87	−.06	80.5	+6.8	110	20	96	48	6	65	42	62	52	46	.44	−2.6	6	7,142	e.	35	nw.	5	18	11	2	3.0	.0	.0
Sioux City	1,138	64	106	28.68	29.86	−.09	80.3	+6.0	107	20	92	49	7	69	32	67	61	56	4.93	+1.4	9	7,336	se.	30	se.	8	17	9	5	3.7	.0	.0
Huron	1,306	60	74	28.52	29.88	−.06	77.9	+6.1	111	20	91	49	7	65	36	64	55	52	2.11	−1.0	13	7,634	se.	42	nw.	5	20	10	1	3.0	.0	.0
Northern Slope							**72.7**	**+4.9**										44	**0.78**	**−0.8**										**3.7**		
Billings	3,140	4																														
Havre	2,505	11	67	27.32	29.90	−.01	71.6	+3.3	100	30	87	41	6	56	46	55	42	42	.21	−1.7	2	6,473	sw.	44	sw.	7	17	12	2	2.9	.0	.0
Helena	4,124	85	111	25.80	29.90	−.03	69.6	+3.9	99	29	83	46	6	56	39	54	43	44	.24	−.9	6	6,385	sw.	39	sw.	7	14	13	4	4.0	.0	.0
Kalispell	2,973	48	56	26,92	29.91	−.02	67.0	+2.9	101	28	82	43	23	52	41	52	41	46	.27	−.8	3	5,201	w.	21	w.	2	14	15	2	3.6	.0	.0
Miles City	2,371	48	55	27.41	29.89	−.03	78.2	+5.3	105	20	92	42	6	65	44	58	43	35	.67	−.9	2	5,408	ne.	29	n.	10	17	11	3	3.5	.0	.0
Rapid City	3,259	50	58	26.60	29.91	−.02	76.6	+5.6	104	18	90	46	6	63	43	61	52	47	.59	−1.8	8	5,882	n.	28	n.	5	15	15	1	3.9	.0	.0
Cheyenne	6,094	50	71	24.10	29.90	−.02	72.7	+6.0	97	15	87	45	6	58	41	54	43	43	2.52	+.4	9	6,560	nw.	38	w.	10	9	14	8	5.2	.0	.0
Lander	5,372	60	68	24.70	29.89	−.03	72.0	+4.6	97	17	88	45	6	56	42	54	39	38	1.35	+.7	9	4,487	sw.	28	sw.	20	16	14	1	3.3	.0	.0
Sheridan	3,790	10	47	26.09	29.90		73.0		102	19	91	47	6	55	47	57	45	46	.40	−.8	4	3,765	nw.	27	nw.	3	18	12	1	3.2	.0	.0
Yellowstone Park	6,241	11	48		29.97	+.05	64.0	+2.5	88	28	79	41	8	49	41			50	.81	−.5	10	6,057	sw.	37	sw.	29	10	17	4		.0	.0
North Platte	2,821	11	51	27.01	29.84	−.09	83.0	+10.1	108	15	98	56	7	68	41	64	54	48	.79	−2.0	6	5,573	s.	35	w.	5	16	12	3	3.9	.0	.0

TABLE 1.—*Climatological data for Weather Bureau stations, June 1934*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01 or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	Pct.	In.	In.		Miles								0-10	In.	In.
Middle Slope							**85.0**	**+7.9**										**38**	**0.91**	**-1.9**										**3.4**		
Denver	5,292	106	113	24.79	29.90	-0.01	77.8	+5.6	100	19	91	56	1	65	35	57	43	36	0.32	-1.4	8	5,812	s.	27	n.	27	8	18	5	5.0	0.0	0.0
Pueblo	4,865	80	86	25.33	29.88	-.03	80.0	+5.8	102	13	96	54	1	64	42	58	45	38	.85	-.1	7	5,457	nw.	37	nw.	11	11	18	2	4.5	0	0
Concordia	1,392	50	58	28.45	29.87	-.08	88.4	+10.4	114	13	102	55	7	75	36	67	54	38	.95	-2.8	4	6,539	s.	29	w.	5	19	10	2	3.3	.0	.0
Dodge City	2,509	10	86	27.36	29.87	-.06	87.3	+8.9	109	31	101	61	7	74	35	64	50	34	.43	-2.7	5	9,805	s.	32	n.	5	24	7	0	2.1	.0	.0
Wichita	1,358	85	93	28.49	29.86	-.10	88.2	+8.8	109	31	100	62	7	76	34	67	56	39	1.77	-1.6	4	8,734	s.	31	n.	13	21	9	1	2.6	.0	.0
Oklahoma City	1,214	10	47	28.67	29.91	-.05	88.3	+7.7	106	30	100	65	7	76	32	68	59	43	.13	-2.7	2	7,192	s.	21	s.	31	20	7	4	3.1	.0	.0
Southern Slope							**84.9**	**+3.7**										**45**	**0.77**	**-1.6**										**2.7**		
Abilene	1,738	10	52	28.15	29.90	-.03	87.2	+4.4	104	30	100	68	7	75	34	68	58	46	.52	-1.6	3	7,345	s.	28	se.	6	24	3	4	2.4	.0	.0
Amarillo	3,676	10	49	26.29	29.90	-.02	84.1	+7.3	105	31	97	64	7	71	33	63	51	38	.19	-2.6	2	7,070	s.	21	ne.	27	20	10	1	2.9	.0	.0
Big Spring	2,537	5	62	27.37	29.91	......	84.2	......	101	30	97	66	5	72	32	66	57	47	1.92	......	5	......	s.	......	......	......	23	7	1	2.2	.0	.0
Del Rio	944	64	71	28.90	29.86	-.04	85.6	-.7	100	18	95	70	26	76	27	71	64	57	2.23	-.2	5	7,876	se.	37	e.	26	15	12	4	4.1	.0	.0
Roswell	3,566	75	85	26.37	29.86	-.02	82.6	+3.7	103	31	96	65	10	69	36	62	50	38	.13	-2.1	3	6,370	s.	29	nw.	21	22	9	0	2.0	.0	.0
Southern Plateau							**82.0**	**+3.0**										**41**	**0.59**	**-0.6**										**3.1**		
El Paso	3,778	152	175	26.17	29.83	-.01	84.8	+3.7	101	14	96	67	19	73	29	64	52	38	.19	-1.8	4	6,747	e.	33	s.w	18	23	8	0	2.0	.0	.0
Albuquerque	4,972	5	39	25.09	29.81	......	79.5	......	102	14	95	58	2	64	39	50	48	42	.61	......	8	7,070	n.	39	ne.	11	11	18	2	4.1	.0	.0
Santa Fe	7,013	38	53	23.39	29.88	.00	71.8	+2.8	92	31	85	52	6	59	32	55	45	46	1.98	-.4	11	4,914	e.	21	sw.	29	9	18	4	5.1	.0	.0
Flagstaff	6,907	10	59	23.47	29.86	+.03	68.4	+3.4	92	13	84	47	8	53	39	53	......	52	1.77	......	10	6,250	sw.	29	s.	28	5	17	9	......	.0	.0
Phoenix	1,108	10	107	28.66	29.77	-.01	94.0	+4.2	116	11	107	74	20	81	34	69	55	32	.11	-1.0	2	5,251	w.	30	nw.	28	22	5	4	2.9	.0	.0
Yuma	141	9	54	29.62	29.76	.00	93.0	+2.2	116	10	107	68	25	79	44	72	60	38	T	-.2	0	5,164	s.	23	se.	28	29	2	0	1.6	.0	.0
Independence	3,957	5	26	25.96	29.89	+.06	79.8	+1.7	109	27	97	50	8	62	45	55	......	......	.65	+.5	1	......	s.	......	......	......	25	3	3	......	.0	.0
Middle Plateau							**76.3**	**+3.8**										**29**	**0.31**	**-0.2**										**2.2**		
Reno	4,527	61	76	25.49	29.89	+.02	71.6	+4.1	100	28	89	42	7	54	44	52	36	33	T	-.2	0	5,802	w.	25	w.	14	28	2	1	.8	.0	.0
Tonopah	6,090	12	20	......	......	......	75.3	......	96	27	87	53	24	63	30	52	34	27	.11	......	1	......	se.	......	......	......	......	......	......	......	.0	.0
Winnemucca	4,344	18	56	25.60	29.90	.00	73.8	+3.2	106	28	94	42	5	54	55	50	29	24	.02	-.2	1	5,612	sw.	28	s.	28	28	3	0	.8	.0	.0
Modena	5,473	10	46	24.65	29.84	-.02	73.6	+3.0	98	27	91	48	5	57	46	52	33	31	.54	-.5	3	8,633	sw.	33	sw.	7	19	7	5	3.1	.0	.0
Salt Lake City	4,360	86	210	25.60	29.86	-.04	79.7	+4.0	103	28	93	56	5	67	36	57	39	28	.68	+.2	8	6,117	nw.	32	sw.	21	19	8	4	2.8	.0	.0
Grand Junction	4,602	60	68	25.37	29.84	-.05	82.6	+4.9	103	14	97	58	6	68	37	58	41	29	.30	-.3	6	5,501	se.	30	s.	19	18	11	2	3.3	.0	.0
Northern Plateau							**73.1**	**+2.5**										**35**	**0.18**	**-0.3**										**2.5**		
Baker	3,471	48	53	26.45	29.96	+.01	67.6	+2.0	104	28	84	29	22	51	43	52	39	42	.01	-.6	1	4,813	n.	21	sw.	28	23	8	0	2.7	.0	.0
Boise	2,739	79	87	27.10	29.88	-.05	76.1	+3.2	108	27	92	52	22	60	38	56	39	32	.41	+.2	2	4,249	nw.	26	nw.	30	22	8	1	2.6	.0	.0
Pocatello	4,477	60	68	25.47	29.86	-.06	75.2	+4.4	102	28	90	51	8	60	39	53	32	27	.56	-.2	2	6,496	se.	38	sw.	30	17	12	2	3.0	.0	.0
Spokane	1,929	101	110	27.92	29.92	-.04	71.3	+2.3	106	27	85	46	21	58	35	54	38	36	T	-.7	0	5,736	s.	22	se.	7	22	6	3	2.7	.0	.0
Walla Walla	991	57	65	28.87	29.92	-.05	75.2	+1.2	106	27	88	53	22	62	36	56	40	34	.06	-.3	1	4,607	s.	19	sw.	7	24	5	2	1.8	.0	.0
Yakima	1,076	58	67	28.81	29.94	......	73.4	+2.0	103	27	88	49	22	59	37	56	42	39	.01	-.3	1	5,546	nw.	20	n.	2	25	3	3	2.0	.0	.0
North Pacific Coast Region							**62.2**	**+0.3**										**68**	**0.95**	**+0.2**										**5.0**		
North Head	211	11	56	29.87	30.09	+.01	57.6	+.4	67	31	61	51	1	54	11	55	53	86	.81	-.2	10	10,079	n.	50	s.	15	4	12	15	6.8	.0	.0
Seattle	125	90	321	29.92	30.05	+.01	63.9	+.8	80	24	72	52	7	55	25	56	50	65	.83	+.2	4	6,143	n.	28	sw.	16	8	15	8	5.3	.0	.0
Tatoosh Island	86	10	54	29.99	30.09	+.04	55.0	-.1	62	22	58	49	4	52	11	53	52	90	3.88	+2.3	14	7,198	s.	41	s.	15	4	6	21	7.7	.0	.0
Medford	1,329	29	58	28.56	29.94	......	71.0	......	95	1	88	47	22	54	43	56	46	49	.02	-.3	1	5,609	nw.	22	n.	2	26	3	2	1.7	.0	.0
Portland, Oreg	153	68	106	29.88	30.04	-.01	67.0	+.3	88	23	77	52	18	57	30	58	51	61	.11	-.5	2	4,996	nw.	18	nw.	1	12	10	9	4.8	.0	.0
Roseburg	510	45	76	29.49	30.03	.00	67.5	+.1	94	1	81	45	22	54	39	57	49	60	.06	-.3	3	4,186	n.	17	ne.	2	13	14	4	3.9	.0	.0
Middle Pacific Coast Region							**68.4**	**+1.4**										**63**	**T**	**0.0**										**2.7**		
Eureka	62	73	89	30.00	30.07	+.02	57.3	+1.8	68	16	62	48	11	53	15	54	52	86	T	-.1	0	5,099	nw.	17	nw.	7	5	19	7	5.6	.0	.0
Red Bluff	330	5	58	29.52	29.86	-.03	81.2	+.4	109	2	97	56	7	65	41	61	46	35	.00	.0	0	4,513	s.	18	se.	6	29	1	1	.7	.0	.0
Sacramento	69	92	115	29.82	29.88	.00	75.2	+2.0	106	2	92	52	7	58	43	60	50	51	.00	.0	0	7,025	s.	21	sw.	6	30	1	0	.2	.0	.0
San Francisco	155	208	243	29.80	29.97	+.02	60.0	+1.5	77	10	66	51	19	54	23	54	52	80	.01	.0	1	6,586	sw.	25	w.	31	12	14	5	4.3	.0	.0
South Pacific Coast Region							**74.4**	**+1.2**										**61**	**T**	**0.0**										**2.9**		
Fresno	327	97	105	29.53	29.87	+.04	81.8	-.3	109	28	98	55	7	65	37	60	42	31	.00	.0	0	5,891	nw.	18	nw.	1	29	1	1	.5	.0	.0
Los Angeles	338	159	191	29.56	29.91	+.01	72.3	+2.1	95	27	82	58	8	63	29	63	59	70	T	.0	0	4,109	sw.	16	se.	27	16	15	0	3.2	.0	.0
San Diego	87	62	70	29.82	29.91	-.01	69.0	+1.8	84	27	74	59	12	64	17	64	62	81	T	.0	0	5,253	w.	17	s.	27	13	12	6	4.9	.0	.0
West Indies																																
San Juan, P.R.	82	9	54	29.95	30.04	......	79.5	-.6	88	26	84	71	6	75	15	......	......	......	6.84	+.9	20	9,970	e.	29	e.	3	4	21	6	5.9	.0	.0
Panama Canal																																
Balboa Heights	118	6	97	......	[1]29.83	+.01	80.7	+.4	91	28	87	72	23	74	17	......	......	[1]86	5.39	-1.8	15	4,238	nw.	20	nw.	31	0	16	15	7.5	.0	.0
Cristobal	36	6	97	......	[1]29.85	.00	81.8	+1.4	89	30	86	73	31	77	14	77	75	[1]83	9.21	-6.2	23	5,829	n.	30	nw.	23	0	8	23	8.6	.0	.0
Alaska																																
Fairbanks	455	11	87	[2]29.42	[2]29.92	......	56.6	......	80	23	66	34	10	47	36	50	44	67	2.47	......	15	5,703	sw.	31	sw.	8	0	7	24	8.8	.0	.0
Juneau	80	96	116	[2]29.90	[2]29.99	......	57.6	......	85	23	65	43	12	50	30	52	47	73	3.36	......	14	4,406	s.	22	e.	10	9	2	20	6.7	.0	.0
Hawaiian Islands																																
Honolulu	38	86	100	[2]29.99	[2]30.03	......	78.4	+.7	85	19	83	71	1	74	14	71	68	71	.38	-.8	10	6,986	e.	24	ne.	30	15	13	3	3.9	.0	.0

[1] Observations taken bihourly.
[2] Pressure not reduced to mean of 24 hours.

TABLE 2.—*Data furnished by the Canadian Meteorological Service*

JULY 1934

Stations	Altitude above mean sea level, Jan. 1, 1919	Pressure			Temperature of the air						Precipitation		
		Station reduced to mean of 24 hours	Sea level reduced to mean of 24 hours	Departure from normal	Mean max. + mean min. ÷ 2	Departure from normal	Mean maximum	Mean minimum	Highest	Lowest	Total	Departure from normal	Total snowfall
	Feet	In.	In.	In.	°F.	°F.	°F.	°F.	°F.	°F.	In.	In.	In.
Cape Race, Newfoundland	99				54.6		61.8	47.3	74	42	3.54		0.0
Sydney, Cape Breton Island	48	29.87	29.92	−0.01	65.0	+2.7	76.0	54.0	85	44	3.96	+0.31	.0
Halifax, Nova Scotia	88	29.68	29.78	−.18	65.8	+2.4	73.7	57.8	84	49	3.07	−.98	.0
Yarmouth, Nova Scotia	65	29.82	29.89	−.06	61.7	+2.2	70.4	53.0	79	43	.77	−2.70	.0
Charlottetown, Prince Edward Island	38	29.82	29.86	−.04	66.8	+2.7	74.4	59.2	81	48	3.22	−.27	.0
Chatham, New Brunswick	28	29.75	29.78	−.10	66.0	+1.0	78.4	53.7	87	42	3.53	−.66	.0
Father Point, Quebec	20	29.81	29.83	−.02	58.5	+.9	66.9	50.1	77	40	3.36	+.32	.0
Quebec, Quebec	296	29.58	29.90	−.01	68.1	+2.6	77.8	58.4	86	51	4.46	+.20	.0
Doucet, Quebec	1,236				59.6		73.7	45.6	89	29	2.88		.0
Montreal, Quebec	187												
Ottawa, Ontario	236	29.66	29.92	−.02	71.3	+1.8	82.8	59.9	92	52	3.00	−.47	.0
Kingston, Ontario	285	29.62	29.92	−.05	70.0	+1.8	78.3	61.7	88	53	1.24	−1.65	.0
Toronto, Ontario	379	29.55	29.94	−.03	71.4	+3.4	81.5	61.4	93	54	1.58	−1.34	.0
Cochrane, Ontario	930				62.2		73.4	51.1	85	40	2.81		.0
White River, Ontario	1,244	28.65	29.94	.00	59.6	+.1	75.1	44.1	92	31	.99	−1.81	.0
London, Ontario	808				70.6		83.4	57.7	95	44	2.85		.0
Southampton, Ontario	656	29.26	29.97	.00	65.6	+.9	76.6	54.7	90	44	1.24	−.74	.0
Parry Sound, Ontario	688	29.26	29.94	−.02	69.3	+3.3	80.1	58.6	90	50	2.08	−.54	.0
Port Arthur, Ontario	644	29.25	29.95	+.01	63.4	+1.4	73.0	53.9	95	44	2.21	−1.27	.0
Winnipeg, Manitoba	760												
Minnedosa, Manitoba	1,690	28.15	29.93	.00	64.1	+1.9	78.0	50.2	97	37	1.65	−.95	.0
Le Pas, Manitoba	860		29.90		63.8		73.7	53.9	88	43	2.68		.0
Qu'Appelle, Saskatchewan	2,115	27.67	29.88	−.04	64.7	+1.2	78.9	50.6	94	32	1.26	−1.22	.0
Moose Jaw, Saskatchewan	1,759				68.1		82.0	54.2	96	35	1.39		.0
Swift Current, Saskatchewan	2,392	27.38	29.84	−.07	67.8	+1.3	82.8	52.7	96	34	1.43	−1.01	.0
Medicine Hat, Alberta	2,365	27.40	29.83	−.07	69.1	+1.3	83.3	55.0	99	43	.77	−1.32	.0
Calgary, Alberta	3,540												
Banff, Alberta	4,521												
Prince Albert, Saskatchewan	1,450												
Battleford, Saskatchewan	1,592	28.18	29.90	.00	63.6	−1.1	77.7	49.4	93	38	1.20	−1.14	.0
Edmonton, Alberta	2,150												
Kamloops, British Columbia	1,262												
Victoria, British Columbia	230	29.79	30.04	−.01	59.4	−.6	67.0	51.7	81	49	.25	−.15	.0
Barkerville, British Columbia	4,180												
Estevan Point, British Columbia	20												
Prince Rupert, British Columbia	170												
Hamilton, Bermuda	151												

LATE REPORTS FOR JUNE 1934

Stations	Altitude above mean sea level, Jan. 1, 1919	Station reduced to mean of 24 hours	Sea level reduced to mean of 24 hours	Departure from normal	Mean max. + mean min. ÷ 2	Departure from normal	Mean maximum	Mean minimum	Highest	Lowest	Total	Departure from normal	Total snowfall
Cape Race, Newfoundland	99				45.2		52.0	38.4	63	27	2.82		0.0
Sydney, Cape Breton Island	48	29.82	29.87	−0.08	53.3	−2.1	64.1	42.5	79	29	1.52	−1.71	.0
Halifax, Nova Scotia	88	29.64	29.74	−.21	56.1	−1.6	64.7	47.5	80	39	4.03	+.27	.0
Yarmouth, Nova Scotia	65	29.77	29.84	−.11	55.0	.0	62.5	47.6	72	38	2.62	−.31	.0
Charlottetown, Price Edward Island	38	29.80	29.84	−.08	56.1	−1.3	63.7	48.5	77	40	1.65	−1.02	.0
Chatham, New Brunswick	28	29.73	29.76	−.13	58.0	−2.0	68.6	47.4	90	34	4.66	+1.20	.0
Father Point, Quebec	20	29.79	29.81	−.06	51.6	−1.4	58.9	44.3	73	34	4.08	+1.10	.0
Quebec, Quebec	296	29.55	29.86	−.06	61.5	+.3	69.4	53.5	84	42	5.67	+2.02	.0
Doucet, Quebec	1,236				56.0		68.5	43.5	90	20	6.03		.8
Montreal, Quebec	187												
Ottawa, Ontario	236	29.58	29.84	−.10	66.4	+1.1	76.8	56.0	94	41	3.09	+.17	.0
Kingston, Ontario	285	29.55	29.86	−.11	64.8	+1.4	73.3	56.4	86	48	3.18	+.75	.0
Toronto, Ontario	379	29.47	29.86	−.11	67.8	+4.4	78.9	56.8	94	49	2.75	−.05	.0
Cochrane, Ontario	930				57.7		68.8	46.6	84	27	4.62		.6
White River, Ontario	1,244	28.57	29.87	−.07	56.2	−2.5	70.3	42.1	84	32	1.64	−.58	.0
London, Ontario	808				68.4		82.1	54.8	94	42	.94		.0
Southampton, Ontario	656	29.18	29.89	−.08	59.8	−.6	67.1	52.4	92	40	1.83	−.52	.0
Parry Sound, Ontario	688	29.18	29.86	−.10	63.3	+1.6	73.5	53.2	89	39	2.26	−.16	0
Port Arthur, Ontario	644	29.17	29.88	−.06	57.2	+.8	66.0	48.4	85	40	3.15	+.42	.0
Winnipeg, Manitoba	760	29.05	29.87	−.02	61.1	−1.1	71.5	50.7	90	38	4.15	+.86	.0
Minnedosa, Manitoba	1,690	28.08	29.87	−.02	59.3	−.3	70.7	47.9	84	38	3.41	+.41	.0
Le Pas, Manitoba	860		29.87		58.9		68.5	49.3	79	37	3.39		.0
Qu'Appelle, Saskatchewan	2,115	27.61	29.83	−.04	57.0	−2.9	69.0	45.0	80	34	3.96	+.54	.0
Moose Jaw, Saskatchewan	1,759				59.1		70.4	47.8	82	38	3.62		.0
Swift Current, Saskatchewan	2,392	27.34	29.82	−.05	58.6	−1.4	69.8	47.5	70	39	4.87	+2.20	.0
Medicine Hat, Alberta	2,365	27.36	29.81	−.04	60.3	−1.7	71.1	49.5	82	40	4.72	+1.96	.0
Calgary, Alberta	3,540	26.25	29.89	+.05	54.0	−2.0	64.3	43.8	82	29	4.02	+1.57	.0
Banff, Alberta	4,521	25.40	29.92	+.08	52.4	+.9	66.1	38.7	80	30	.81	−2.52	.0
Prince Albert, Saskatchewan	1,450	28.34	29.90	+.03	57.0	−.7	67.6	46.4	78	38	6.81	+4.30	.0
Battleford, Saskatchewan	1,592	28.16	29.89	+.03	56.4	−3.1	68.5	44.2	82	30	5.19	+1.88	.0
Edmonton, Alberta	2,150	27.64	29.89	+.05	55.6	−1.3	66.1	45.2	77	35	4.18	+1.32	.0
Edmonton, Alberta (May)	2,150	27.59	29.85	−.03	54.8	+4.0	67.5	42.0	90	29	2.86	+1.31	.8
Kamloops, British Columbia	1,262	28.64	29.91	+.04	65.2	+1.4	79.4	51.0	89	41	.73	−.69	.0
Victoria, British Columbia	230	29.77	30.02	+.01	57.8	+1.5	65.6	50.1	72	47	.21	−.99	.0
Barkerville, British Columbia	4,180												
Estevan Point, British Columbia	20				53.7		59.1	48.3	67	42	2.17		.0
Prince Rupert, British Columbia	170				52.3		58.0	46.5	70	44	5.70		.0
Hamilton, Bermuda	151	29.96	30.12	.00	76.9	+1.9	81.9	71.9	86	67	3.70	−2.25	.0

SEVERE LOCAL STORMS, JULY 1934

[Compiled by Mary O. Souder]

[The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A revised list of tornadoes will appear in the Annual Report of the Chief of Bureau]

Place	Date	Time	Width of path (yards)	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Cleveland, Ohio	1	2:30 p.m.			$1,000	Tornado	No details	Official, U.S. Weather Bureau.
Tonawanda, N.Y., and vicinity.	1	3:15-3:30 p.m.				Thundersquall	A lightning bolt entered the transforming plant of the New York Central car shops causing several thousand dollars damage and endangered the lives of several workmen; many old trees blown down.	Do.
Marietta, Minn., vicinity of	1	5 p.m.			7,500	Heavy hail and wind.	Some hailstones as large as hen eggs; property damage amounted to $50,000; damage to crops, $25,000.	Do.
Plummer, Minn., and vicinity	1				2,700	Wind	Property damage	Do.
Traverse City, Minn., northeastern portion.	1					Hail	Considerable damage to growing crops	Do.
Clearwater, Nebr., 8 miles south.	2	1 p.m.	[1] 1		4,000	Hail and wind	Property damaged	Do.
Cambridge Springs, Pa., and vicinity.	3	A.m.			7,500	Tornado	Many trees uprooted; several buildings unroofed; house destroyed by lightning.	Do.
Binghamton, N.Y	3	3:14-5 p.m.				Thunderstorm	Several barns destroyed; house damaged by falling tree; roofs blown off.	Do.
Syracuse, N.Y., central section	3	P.m.				Hail and rain	Damage confined to broken glass in skylights and greenhouses.	Do.
New York, western, central, and southern sections of State.	3	do		1		Electrical and wind.	Hundreds of trees blown down, blocking highways and crippling telephone and power lines; 2 barns demolished; many roofs and garages damaged; man killed by high-tension wire blown down by the wind.	Do.
Columbiana County, Ohio	3				31,000	Wind	No details	Do.
Scranton, Pa	3					Wind, electrical	Damage mostly to trees and wires	Do.
Teton County, Idaho	4	11 a.m.	[1] ½-2		30,000	Heavy hail	Considerable loss to crops; path 8 miles long	Do.
Seibert, Colo	4	3 p.m.	[1] 6	1		Heavy rain and hail.	Flood waters due to heavy rains caused the death of 1 person; cattle also lost; slight damage to crops; path 25 miles long.	Do.
Valley Junction, Iowa	4	3:30 p.m.			2,500	Tornado	3 freight cars overturned; shed unroofed, tool house demolished.	Do.
Prairie City, Iowa	4	4 p.m.			12,000	do	Property damaged	Do.
Lanark, Ill	4				725	Electrical	Loss in livestock $225; property damage $500	Do.
Amsterdam, Iowa	4				20,000	Wind	Property damaged	Do.
Dallas and Polk Counties, Iowa.	4				4,000	Thundersqualls	2 barns destroyed by lightning	Do.
Newton, Kellogg, and Grinnell, (near), Iowa.	4				20,000	Tornado	Property damaged	Do.
Pennington, N.Mex	5	3 p.m.	[1] 2			Heavy hail	Gardens destroyed	Do.
Lynchburg (near), Va	5	4:30 p.m.		1		Electrical	Lightning from practically clear sky killed 1 person	Do.
Trempealeau and La Crosse to Monroe Counties, Wis.	5	5:15-6:30 p.m.			245,000	Thundersquall and hail.	Storm entered Wisconsin from Minnesota; 19 barns and many smaller buildings blown down or damaged; trees uprooted and crops flattened; cattle killed; damage from hail amounted to $45,000.	Do.
Holdrege-Lincoln, Nebr	5	7-9 p.m.	[1] 30	2	40,000	Wind	Damage to plate glass, roofs, trees, and electric lines; boy killed by flying timber; death of lineman resulted next morning while repairing power line.	Do.
Lincoln, Pipestone, Rock, Murray, and Cottonwood Counties, Minn.	5	9 p.m.			200,000	Thunderstorm and hail.	Hailstones, varying in size from pea to hen egg, covered the ground to the depth of 2 inches in places; loss to crops, especially corn; half of loss estimated occurred in Pipestone County where some cornfields were entirely ruined; damage to wire systems and trees.	Do.
Hand, Beadle, and Kingsbury Counties, S. Dak.	5	P.m.			20,000	Thundersquall	Damage confined to telephone lines and trees, structural damage; sewer troubles and property damage at the State Fair Grounds.	Do.
Marysville, Mo	5					Tornado	Slight damage to trees and buildings	Do.
Austin, Minn., and vicinity	6	12:15 a.m.	[1] 13			Heavy hail	Severe damage to growing crops; windows broken; hailstones varied in size from peas to jagged chunks of ice, some as large as baseballs.	Do.
Buffalo, N.Y	6	A.m.				Thunderstorm	House struck by lightning; farmhouse, barn, and contents destroyed by fire.	Do.
Detroit, Mich	6	4 p.m.		2	150,000	Line squall	Considerable minor damage throughout city; 2 killed by falling trees; several injured by fallen electric wires; Ford motor plant reported $150,000 damage due to wind blowing sand and grit into bearings of machinery.	Do.
Montague, Calif	6	4:30 p.m.	[1] 5			Wind and hail	Hail damaged grain; wind demolished a barn and damaged trees and roofs.	Do.
Santa Fe, N.Mex	6	5 p.m.	[1] 6			Heavy hail	Gardens ruined; loss in fruit crop	Do.
Sanderson, Tex	6	6:30 p.m.	[1] 1		5,000	Wind	Building and houses damaged; 2 persons injured	Do.
New York, northern portion of of State.	6	P.m.		1		Electrical and wind.	Telephone and power lines damaged; boy killed by lightning; several barns burned.	Do.
Camden, Ark	6					Wind	Considerable damage reported; windows broken and signs blown down.	Do.
Wayne City, Ill	6				5,000	do	Property damaged	Do.
Rhode Island, entire State	7	2:50-5:35 p.m.		1		Severe thunderstorm.	Man killed and 10 persons stunned by lightning; 20 houses and 2 churches struck.	Do.
Havre, Mont	7	5-5:16 p.m.			2,000	Wind and dust	Electric poles and wires down; trees blown over; property damaged.	Do.
Browndale, Minn., vicinity of	8	12:30 a.m.				Heavy hail	Severe damage to crops; windows broken	Do.
Holt and Antelope Counties, Nebr.	8	5-7 p.m.	[1] 2-5		5,000	Hail and wind	Property damaged	Do.
Stanton-Pilger, Nebr	8	6-7 p.m.	[1] 5-7		50,000	Hail, wind, and rain.	Loss to crops; small buildings demolished; trees uprooted; windows broken; basements and highways flooded.	Do.
Sibley, Nicollet, Le Sueur, Rice and Goodhue Counties, Minn.	9	11 p.m.			100,000	Thunder squalls and hail.	Loss to growing crops; considerable damage to trees, silos and farm buildings.	Do.
Bloomfield, Nebr., 8 miles northeast.	9	P.m.	[1] 1		5,000	Hail	Property damaged	Do.

[1] Miles instead of yards.

SEVERE LOCAL STORMS, JULY 1934—Continued

Place	Date	Time	Width of path (yards)	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Guttenberg, Clayton, and Millville, Iowa.	9-10					Heavy rain and hail.	Guttenberg: Crop loss amounted to several thousand dollars. Clayton: Landslide held up train service for several hours on the Chicago, Milwaukee, St. Paul & Pacific R.R. Millville was flooded as a result of creeks overflowing.	Official, U. S. Weather Bureau.
West Union, Iowa, and vicinity	10	A.m.			$75,000	Tornado	Nearly 1,000 trees blown down or badly damaged; telephone lines down; houses unroofed.	Do.
Jacksonville, Ill., and vicinity	10	P.m.			920,000	Tornadic winds and heavy hail.	Business, utility, industrial and residential properties damaged; many large trees blown down; $750,000 damage including $125,000 crop loss in Jacksonville alone; 25 persons injured and several subsequent deaths reported.	Do.
Carbondale, Colo	10					Electrical	A bolt of lightning severely injured a farmer and caused much damage to farm buildings.	Do.
Fairview, Ill., and vicinity	10		[1] 3-4		150,000	Hail	Crop loss and property damage	Do.
Havana, Ill	10				75,000	do	Loss to crops and property damaged	Do.
Virginia, Philadelphia, Illinois, and vicinity.	10		[1] 6		51,000	Wind and hail	Property damage $1,000; crop loss $50,000; path 15 miles long.	Do.
Woodson, Ill	10				1,000	Wind	Property damage; corn blown down	Do.
Bloomfield, Nebr	11	6 p.m.	1,320		3,000	Hail and wind	Property damaged	Do.
Cleveland, Ohio, and vicinity	11	6:28-7:08 p.m.				Thundersquall and hail.	Considerable damage reported	Do.
Trenton, Aviston, and Carlyle, Ill.	11				2,500	Wind	Electric service disabled; property damaged; trees blown down; loss in shocked grain.	Do.
St. Louis, Mo	11					do	Damage to trees and wires in northwestern portion of the city.	Do.
Minonk, Ill	12				2,000	Electrical	Loss in stock; barn destroyed	Do.
Victoria, Ill	12				4,500	Hail	Loss in crops	Do.
Erie, Pa., and vicinity	12					Wind, electrical	Telephone poles down; trees uprooted; property damaged.	Do.
Schroeppel, Hastings, and West Monroe Counties, N.Y.	12	5-6 p.m.	2,640		75,000	Hail and thunderstorm.	Between 10 and 20 small sheds and barns blown down; many trees uprooted; calf killed by being picked up and thrown by the wind. Many windows broken; path 20 miles long.	Do.
Calumet and Manitowoc Counties, Wis.	12	8 p.m.			70,000	Thundersquall and heavy hail.	3 barns destroyed; funnel clouds observed at Reedville and Porter; crop loss from hail $40,000.	Do.
Oswego County, N.Y., and vicinity.	12	P.m.	[1] 2		500,000	Electrical, wind and hail.	Many buildings on dairy farms demolished; chickens killed; windows broken; nearly all crops ruined in path of storm which was from 15 to 20 miles long.	Do.
Hanson County, S.Dak	12	do	[1] 3			Hail	Total loss of crops; path 7 miles long	Do.
Crete to Denton, Nebr	13	4-5 p.m.	[1] 3-5		6,000	Hail and wind	Property damaged	Do.
Scranton, Pa., and vicinity	13	4 p.m.		2	50,000	Hail, electrical	Powder mill destroyed; considerable damage at Pittston; traffic and communication interrupted.	Do.
Odell, Nebr	13	5:30 p.m.	880		8,000	Tornado	Property damaged	Do.
Riley County, Kans	13	7:30 p.m.			1,500	Windsquall	Damage to water tower on the campus of State agricultural college; path narrow and short.	Do.
Washington, Ga	13					Thundersquall	Trees uprooted; property damaged; hangar at airport partially destroyed and plane in it wrecked; electric wires down; lighting service badly interrupted.	Do.
Fairfield and Wayne City, Ill., and vicinity.	13				27,000	Wind	Property damage $25,000; crop loss $2,000	Do.
Hindsboro, Arcola, and Tuscola, west into Moultrie and Platt Counties, Ill.	13		[1] 5-10		300,000	Hail	Loss to crops; path 20 miles long	Do.
Plymouth to Colmar, Ill	13		[1] 2		6,500	do	$5,000 loss in crops; $1,500 property damage; path 8 miles long.	Do.
Roberts, near, Ill	13		[1] 3		6,000	do	Loss to crops $5,000; property damage $1,000	Do.
Shelbyville to Strasburg, Ill	13				11,500	do	Loss to crops $10,000; other damage $1,500	Do.
Willow Hill, Ill	13		[1] 3		25,000	do	Loss to crops; path 12 miles long	Do.
Bangor, Iowa	13				10,000	do	No details	Do.
Martinsville to Ridgeway, Mo., and vicinity.	13				25,000	Wind	Widespread damage to farm buildings	Do.
Subiaco, Ark	14	6 p.m.			4,000	Tornado	Property damaged over a narrow path	Do.
Carlisle, Pa., and vicinity	14	P.m.			20,000	Electrical	4 barns destroyed	Do.
Pittsylvania County, Va	14	do	[1] 3-5		125,000	Wind and hail	Loss mostly to tobacco crop, practically 100 percent loss in many fields over an area 3 miles wide and 8 miles long; path of entire storm 20 to 30 miles long.	Do.
Springfield, Ill., and vicinity	14				5,500	Heavy hail	Windows broken; damage to roofs, gardens, greenhouses, and trees; loss in tomato crop $4,000.	Do.
Mt. Vernon, Ind	14					do	Considerable damage to corn crop and fruit trees	Do.
Langlade County, Wis	14				250,000	Thunderstorm and hail.	10 to 90 percent of crops destroyed; roofs badly damaged; windows broken; loss to crops in this county $150,000; other damage $100,000.	Do.
Waushara, Green Lake, Fond du Lac, and Calumet Counties, Wis.	14				150,000	Heavy hail	Crop loss $100,000; other damage $50,000	Do.
Onondago County, N.Y	15	3 p.m.				Thundersquall and hail.	Trees blown down blocking traffic; telephone and electric service interrupted; glass in greenhouses broken.	Do.
Neligh, Nebr	15	9 p.m.			4,000	Hail	Property damage	Do.
Pontotoc County, Miss	15				1,000	do	Loss to crops	Do.
Little Rock, Ark., and vicinity	15				40,000	Wind	Windows broken; Dixie Cotton Oil Co. seedhouse unroofed; large number of shade trees blown down.	Do.
Aledo and Nokomis (near), Ill.	15				750	do	In Aledo 75 poles blown down; trees uprooted; near Nokomis $500 property damage; crop loss $250.	Do.
Springfield, Ill. (near)	15				900	Electrical	Property damaged	Do.
Spring Valley, Ill	15				750	do	do	Do.
Ellis, Jackson, Eldora, and York, Iowa.	15				30,000	Wind and hail	8 barns and from 30 to 40 windmills damaged; loss to corn crop.	Do.
Buffalo, N.Y., and vicinity	15			1	1,000	Electrical and hail.	Caddy killed and 2 others injured by lightning at Willowdale Golf Club; $1,000 damage to greenhouses in Williamsville.	Do.
Swormsville, N.Y	15		[1] 1		105,000	Hail	$80,000 crop loss and $25,000 property damage; path 6 miles long.	Do.
Waterloo and Seneca Falls, N.Y.	15					Hail and wind	Much damage to crops and buildings	Do.
Yancey and Mitchell Counties, N.C.	15				90,000	Excessive rain and flood.	Loss to crops; 22 bridges washed away	Do.
North Little Rock, Ark	16					Wind	Several thousand dollars damage; windows broken, signs, awnings and trees blown down.	Do.

[1] Miles instead of yards.

SEVERE LOCAL STORMS, JULY 1934—Continued

Place	Date	Time	Width of path (yards)	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Aledo, Ill	16					Wind	Trees uprooted; wire service crippled	Official, U. S. Weather Bureau.
Calhoun County, Miss	16	P.m		1		Electrical	Boy killed by lightning	Do.
Evansville, Wis	17				$700	Squall	Grandstand at fair grounds unroofed; other minor damage.	Do.
Horry County, S.C	18	3-5 p.m	[1] 2		18,000	Hail	Damage to crops principally tobacco	Do.
Tennessee, middle section	18			1		Thundersquall	Man killed by lightning while fishing; 18 persons injured; trees blown down; cornfield leveled; telephone service disrupted.	Do.
Detroit, Mich	19	1:50 - 5:15 p.m.		1		Electrical	Thunder heard at intervals in northwest section of the city; several children playing in the sun, 1 child was killed by lightning, another, 5 feet away, unharmed; no rain falling at the time.	Do.
Decatur, Ill	19				3,500	do	Damage to wire service $3,000 and buildings $500	Do.
Ramsey, Dakota, Washington, Goodline and Wabasha Counties, Minn.	19					Thunderstorm and hail.	Considerable damage to property and trees; loss to growing crops.	Do.
Cleveland County, N.C	19			1		Thundersquall	House and large barn with contents burned after being struck by lightning; boy killed, the mule he was driving also killed; man standing nearby shocked and burned.	Do.
Hartsville, S.C	19	P.m			2,000	Electrical	Barn struck by lightning and burned	Do.
Amelia County, Va	20	5 p.m	880		2,000	Hail	Loss to crops	Do.
Wilson, N.C	20	P.m				Tornado	Trees broken; chicken houses and other small buildings blown over; porch furniture blown off, rocker carried across the street onto another porch.	Do.
Jefferson, S.C	20	do			1,000	Thunderstorm	Church struck by lightning and partially burned	Do.
Colton and Rensselaer Falls, N.Y.	20			2	20,000	Thundersquall and hail.	Lightning damaged the plant of the St. Lawrence Power Corporation near Colton, N.Y., with $20,000 loss; in Rensselaer Falls trees were uprooted or broken; corn and other crops ruined by hail; 2 persons electrocuted by high-tension wires brought down by the wind.	Do.
Harrisburg, Pa., 6 miles north	21	P.m		1		Electrical	Farmer killed by lightning and several others, in vicinity working in the fields or playing golf at the country club, stunned.	Do.
Susquehanna, Pa	21	do		1	5,000	do	Man killed and several stunned by lightning; barn destroyed.	Do.
Pacolet, S.C	21	do		1		Wind	Man killed and 25 others shocked during ball game, wind unroofing stand carrying with it some protective wiring which came in contact with a small power line, the current being carried into wet ground onto which the persons stepped.	Do.
Wytheville (near), Va	21	do			1,000	Wind, electrical	Barn struck by lightning and burned	Do.
Penasco, N.Mex	21	1 p.m	[1] 1			Heavy hail	Considerable damage to gardens	Do.
Abingdon, near, Va	21	2:30 p.m	[1] 8		7,500	Electrical and wind.	4 barns containing feed, machinery, and equipment destroyed.	Do.
Pulaski County, Va	21	3 p.m	[1] 5			Hail	Considerable loss in corn crop, amount not estimated.	Do.
Shelby County, Ohio	22				30,000	Wind	No details	Do.
Fergus, Judith Basin, and Valley Counties, Mont.	23	4-6 a.m			75,000	Hail	Crop loss, damage to property	Do.
Wortham, Tex	24	5 p.m	200		15,000	Tornado	Property damaged; several buildings demolished; 3 persons injured.	Do.
Kemp, Tex	24	5:30 p.m	[1] 1		6,000	Wind	$5,000 damage to poorly constructed houses; $1,000 loss to crops, mostly corn; path 5 miles long.	Do.
Indianapolis, Ind., and vicinity	24	5:30-6 p.m.	33-800		11,000	Tornado	Man seriously injured when the railroad tower in which he was working was blown over; trees uprooted; roofs and porches blown off; communication and power line poles blown down.	Do.
Sandpoint, Idaho	24	8:15 p.m	1,320		25,000	Hail and wind	Crops damaged; trees blown down breaking power lines; some small buildings unroofed; path 10 miles long.	Do.
Hardin County, Ohio	24					Wind	Amount of damage estimated to be in the thousands.	Do.
Gonzales, Tex	24		300		2,250	Tornado	$1,500 property damage; crop loss $750; path 20 miles long.	Do.
Stillwater and Ravalli Counties, Mont.	24			1	60,000	Hail, electrical	Damage estimated for Stillwater County only; lightning killed 1 person and injured another in Ravalli County.	Do.
Taylor, Tex	24					Tornado	Houses unroofed; trees uprooted	Do.
Calhoun, Nueces, San Patricio, Bee, Jim Wells, Goliad, and Live Oak Counties, Tex.	24-25			19	4,500,000	Tropical storm	Damage from high tides along the coast from Nueces County to Jefferson County; 85 percent of amount stated, crop loss; numerous minor injuries reported.	Do.
Johnson County, Kans	25	3:30 p.m	300			Tornado	Originated 2 miles south and 1 mile east of Olathe, passed north of Stanley where a large barn and shed were demolished; buildings and 9 telegraph poles damaged; path 10 miles long.	Do.
Hoges Store, Eggleston and Berton, Va.	25	6 p.m	[1] 7		5,800	Hail	Damage to crops and buildings; path 12 miles long	Do.
Hopkinton, N.Y	25	P.m		1		Wind and rain	Man electrocuted while attempting to crawl through the fence on his way home in the evening; investigation showed that a power line of the Niagara Hudson Power Corporation had fallen during the storm causing the fence to be charged with electrical current.	Do.
Wilkes-Barre, Pa	25	do			20,000	Electrical and rain	5 churches and radio station damaged by lightning; much damage by flooding.	Do.
Montoursville, Pa	25	do			12,000	Electrical	22 Holstein cows killed	Do.
Lowesville, Va. (near)	25	do				do	Barn including quantity of feed and equipment burned; amount of loss not estimated.	Do.
Woodbury, Berlin, Middletown and Cheshire, Conn.	25				25,000	do	3 buildings destroyed and 6 fires started by lightning.	Do.
Glenarm, Ill	25					do	Barn burned; loss included 9 horses and mules	Do.
Paris, Ill	25					do	9 head of stock killed; 3 injured	Do.
Roberts, near, Ill	25				8,000	Electrical	2 barns burned	Do.
Lupus and Wooldridge, Mo	25				15,000	Wind	Damage to farm buildings; livestock injured; wires down.	Do.
Nashville, Tenn., and vicinity	25			1		Electrical and wind.	Telephone poles and trees blown down; man killed while fishing near Madison, 2 others stunned by lightning.	Do.

[1] Miles instead of yards.

SEVERE LOCAL STORMS, JULY 1934—Continued

Place	Date	Time	Width of path (yards)	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
San Antonio, Tex	25				$12,000	Tropical hurricane.	Storm moved inland on Texas coast; wind velocity 43 miles from the northeast in San Antonio; many trees and light and telephone wires blown down.	Official, U. S. Weather Bureau.
Sun Prairie, Wis	25				2,000	Hail and wind	Roof of factory blown off; trees blown down	Do.
Chatham, Va., vicinity of	25–26	3:30–6 p.m.	[1] 2		60,000	Thundersquall and hail.	Loss in tobacco crop 50 to 80 percent; electric service suspended; path 3 miles long; 2 storms, damage of second not estimated.	Do.
Peekskill, N.Y	26					Electrical and rain.	Storm waters flooded the quarters of the 71st and 174th Regiments at Camp Smith washing away tents and crippling telephone lines and inundating the parade grounds; member of C.C.C. struck by lightning and critically injured.	Do.
Ulster County, N.Y., southern portion.	26					Hail	Considerable damage to apples, grapes and tomatoes.	Do.
Dyer, Tenn	26				10,000	Tornado	2 persons injured; small buildings damaged	Do.
Cheyenne, Wyo	26	4:31–5:10 p.m.	[1] 2½		6,000	Hail and rain	Heavy hail fell at the station, some stones 1¾ inches in diameter, resulting in considerable damage; sunshine recorder broken and cups of anemometer badly dented; trees stripped of half their leaves; nearly all gardens ruined.	Do.
Grantsburg, Ill	27			1		Electrical	Man killed	Do.
Many, La	27	5 p.m			4,400	Thunderstorm	Damage to buildings	Do.
Chambersburg, Pa	27				50,000	Thundersquall	Communication lines out of order; cellars flooded; several barns burned.	Do.
Cushing, Tex	27	5 p.m	880		300	Tornado	Damage to buildings over path 1½ miles long	Do.
Roanoke, Va., and vicinity	27	6–7:15 p.m.		2	210,000	Thundersquall, heavy rain.	Buildings flooded; 5,000 telephones out of commission; loss in crops not estimated; 2 persons killed by lightning; damage from lightning over the State $10,000.	Do.
Scranton and northern Pennsylvania.	27–28				100,000	Electrical; heavy rain.	Much flood damage; sewer system and mines flooded at Scranton; oil damage in Wayne County.	Do.
New York, N.Y., and vicinity	28			1		Electrical and rain.	Considerable damage from lightning and flooding; man killed while working in his garden; bus skidded into pole injuring 4 persons; heavy rain brought joy to potato growers in Suffolk County; they had been threatened with loss of their late crop valued at $1,000,000.	Do.
Racine, Pine River, and Redgranite, Wis.	29		[1] 1–1½		2,000	Hail	Loss to crops; path 17 miles long	Do.
Boise, Idaho	30	2:45–3 p.m.			3,000	Wind	Telephone and electric wires down; number of shade trees uprooted; roofs damaged by falling trees.	Do.
Cortland, N.Y	30	P.m	880			Hail and wind	Thousands of dollars' loss to crops, trees, and gardens.	Do.
Thornburg, Ark	30					Hail	Considerable loss in melons, truck, and fruit	Do.
Jefferson City, near, Missouri	31				5,000	Tornadic winds	Property damaged; 3 persons injured.	Do.

[1] Miles instead of yards.

LATE REPORTS, JUNE 1934

Place	Date	Time	Width of path (yards)	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Hall County, Ga	1–5				$110,000	Rain and hail	Great deal of replanting of corn and cotton necessitated in the northern and southeastern portions of the county; erosion from heavy rains responsible for much damage.	Official, U.S. Weather Bureau.
Oakwood, Okla. (near)	13	5:30–7 p.m.	[1] 3		5,000	do	Loss principally to crops	Do.
Arnett, Okla., vicinity of	15	6–10:30 p.m.	[1] 3		6,000	2 hailstorms	Considerable damage to crops, chiefly wheat; path 8 to 10 miles long.	Do.
Thomas, Okla., vicinity of	15	6 p.m			45,000	Hail	Damage to growing crops	Do.
Erick, Okla., vicinity of	16	5 p.m	2,640		7,500	do	Principal loss to cotton crop; path 5 miles long	D9.
Canton, Okla	16	1–1:30 a.m.	[1] 4		40,000	Hail and wind	Loss to cotton and wheat crops; some property damage, path 30 miles long.	Do.
Blaine County, Okla	16	9–11 p.m.			12,000	do	Damage to growing crops	Do.

[1] Miles instead of yards.

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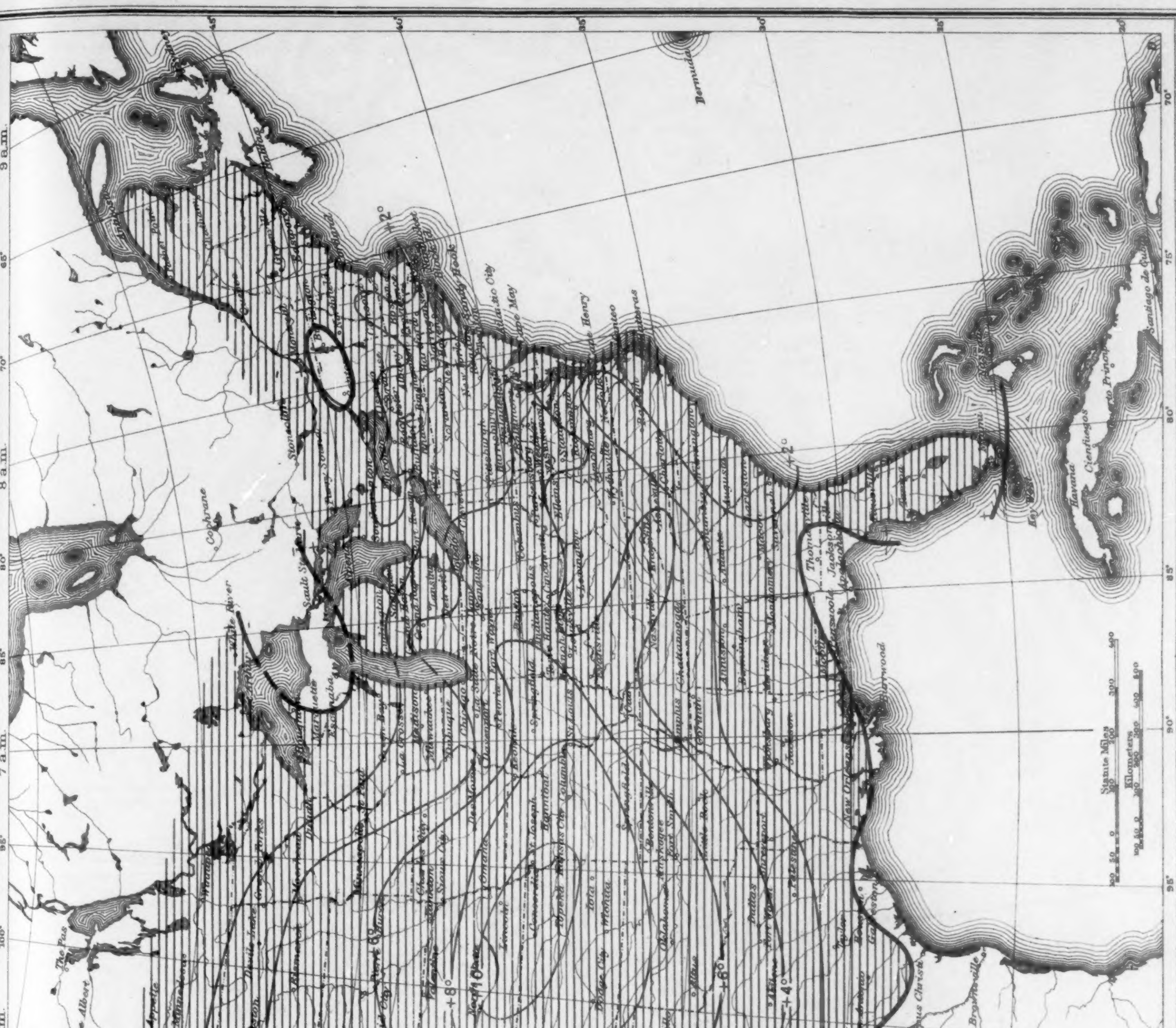
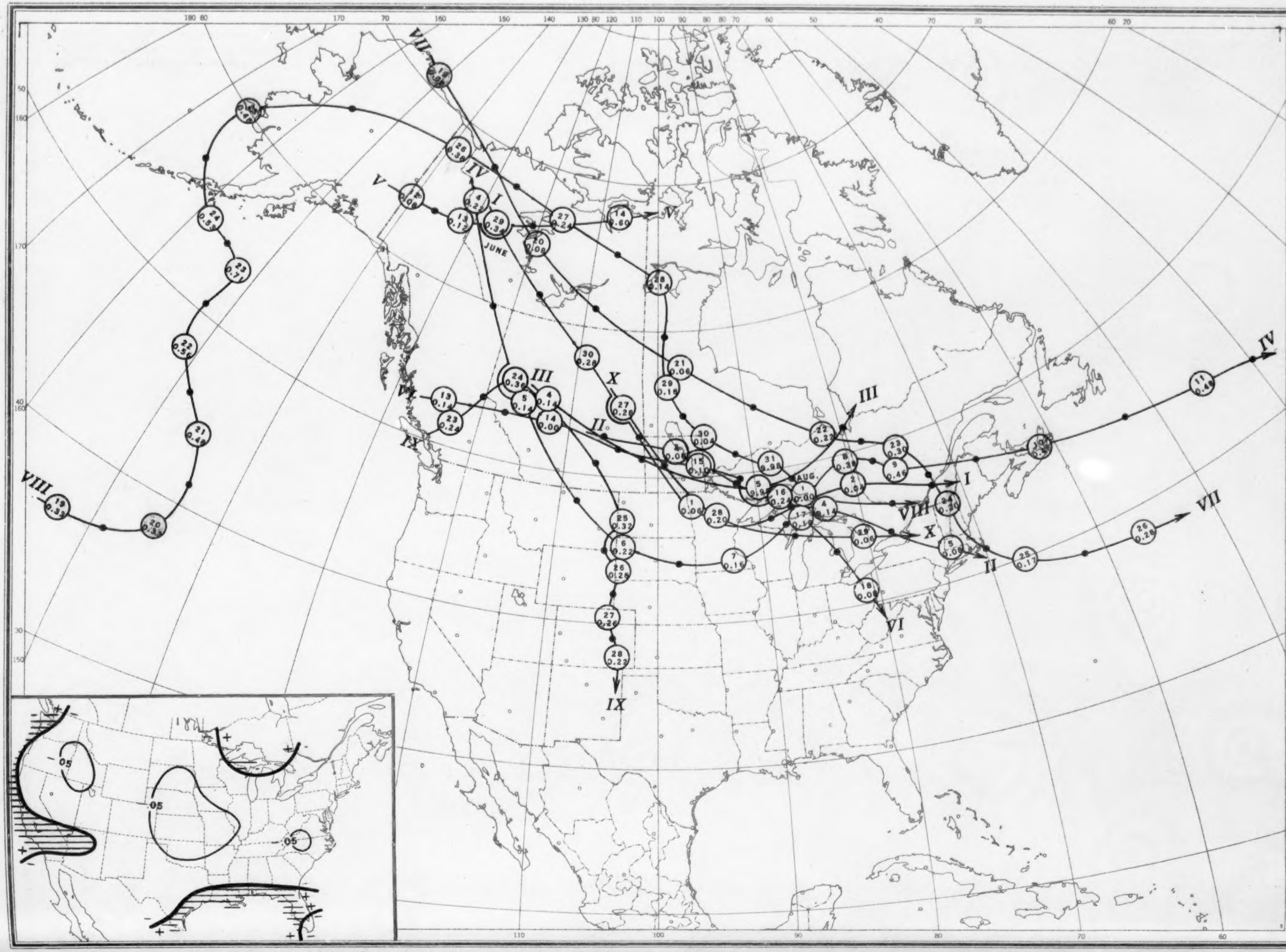
Chart I. Departure (°F.) of the Mean Temperature from the Normal, July 1934



Shaded portions show excess (+)
Unshaded portions show deficiency (−)
Lines show amount of excess or deficiency

Chart II. Tracks of Centers of Anticyclones, July 1934. (Inset) Departure of Monthly Mean Pressure from Normal

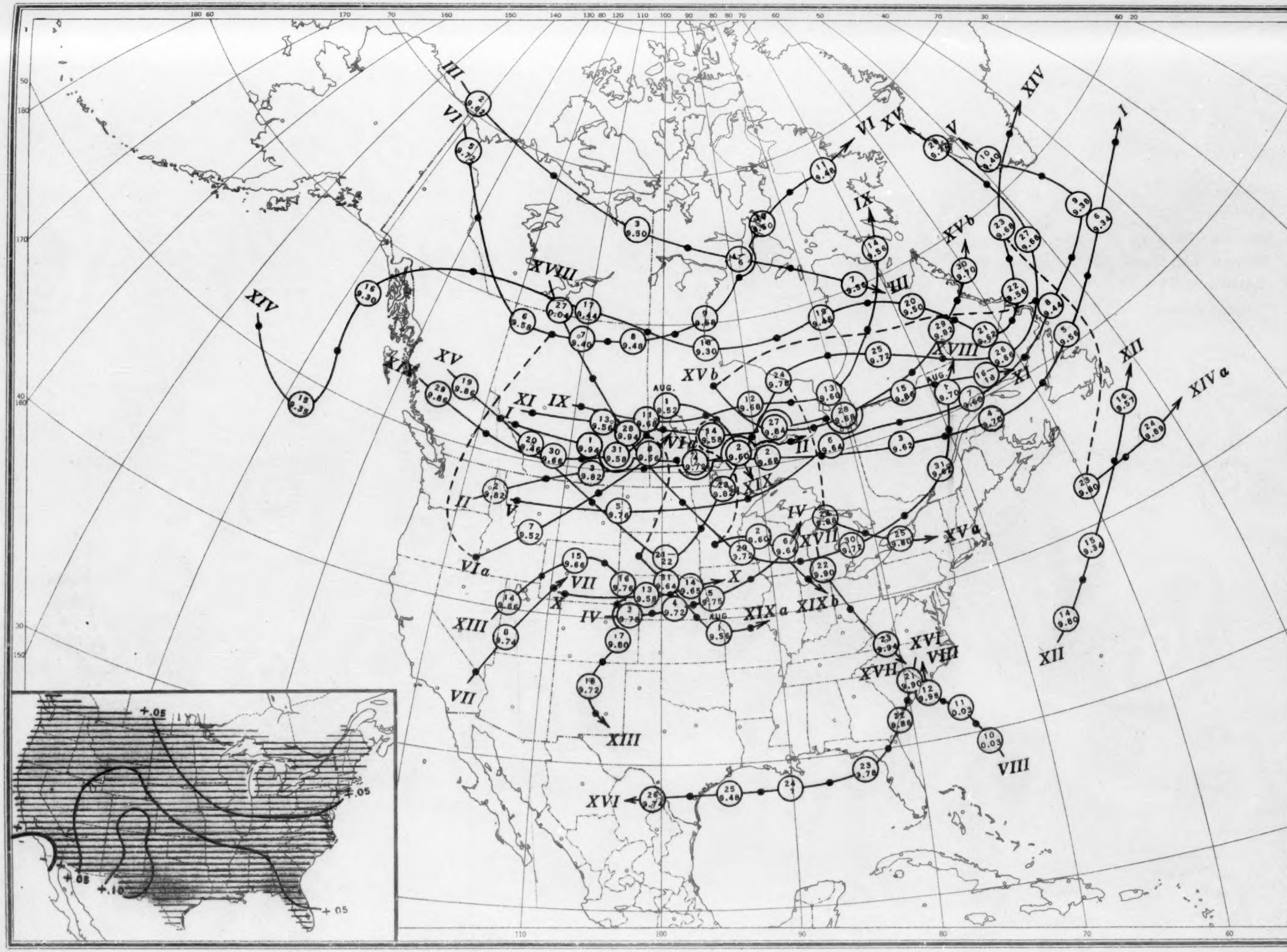
(Plotted by W. R. Stevens)



Circle indicates position of anticyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of anticyclone at 8 p. m. (75th meridian time).

Chart III. Tracks of Centers of Cyclones, July 1934. (Inset) Change in Mean Pressure from Preceding Month

(Plotted by W. R. Stevens)



Circle indicates position of cyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of cyclone at 8 p. m. (75th meridian time).

Chart IV. Percentage of Clear Sky between Sunrise and Sunset, July 1934

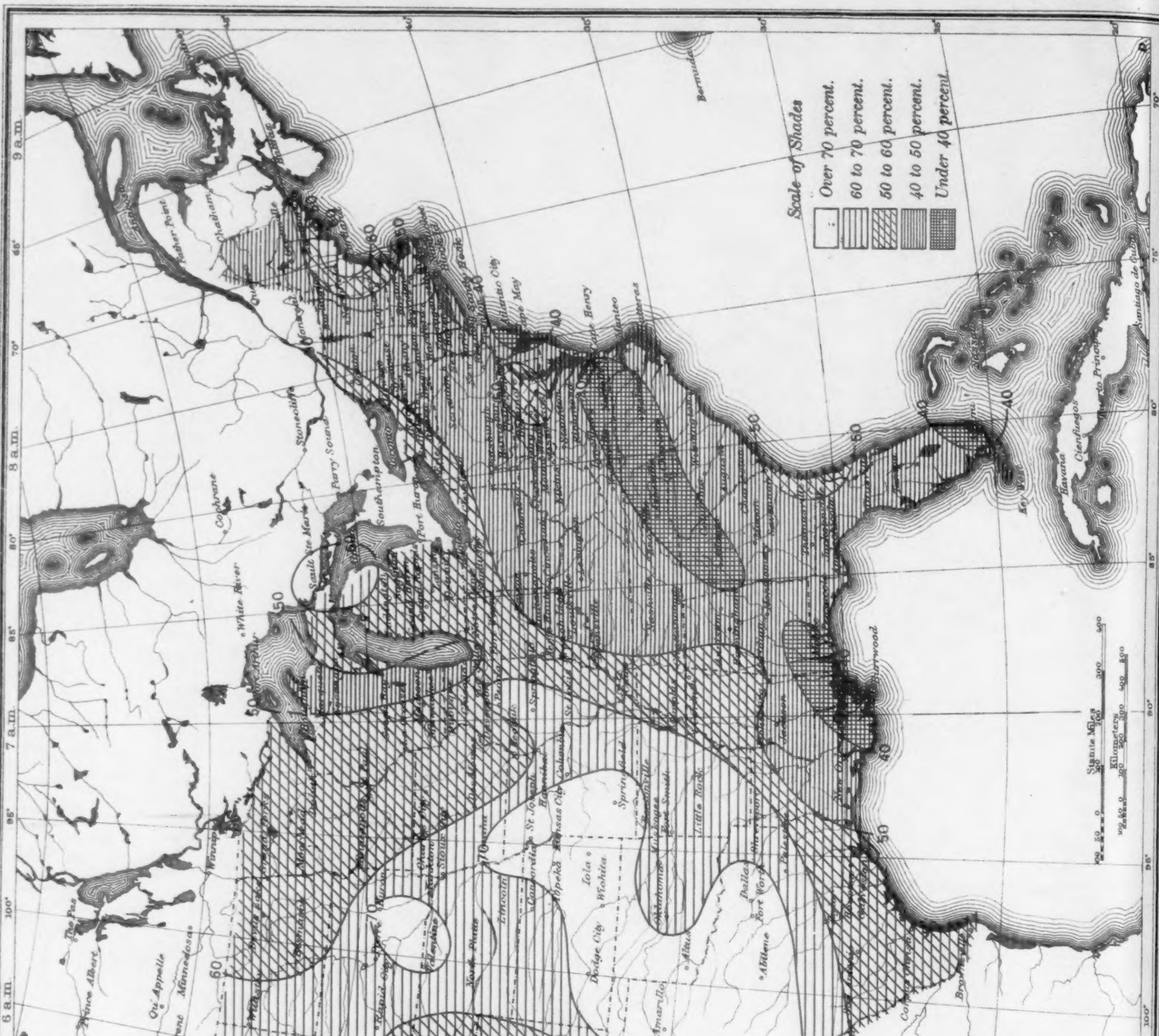


Chart V. Total Precipitation, Inches, July 1934. (Inset) Departure of Precipitation from Normal

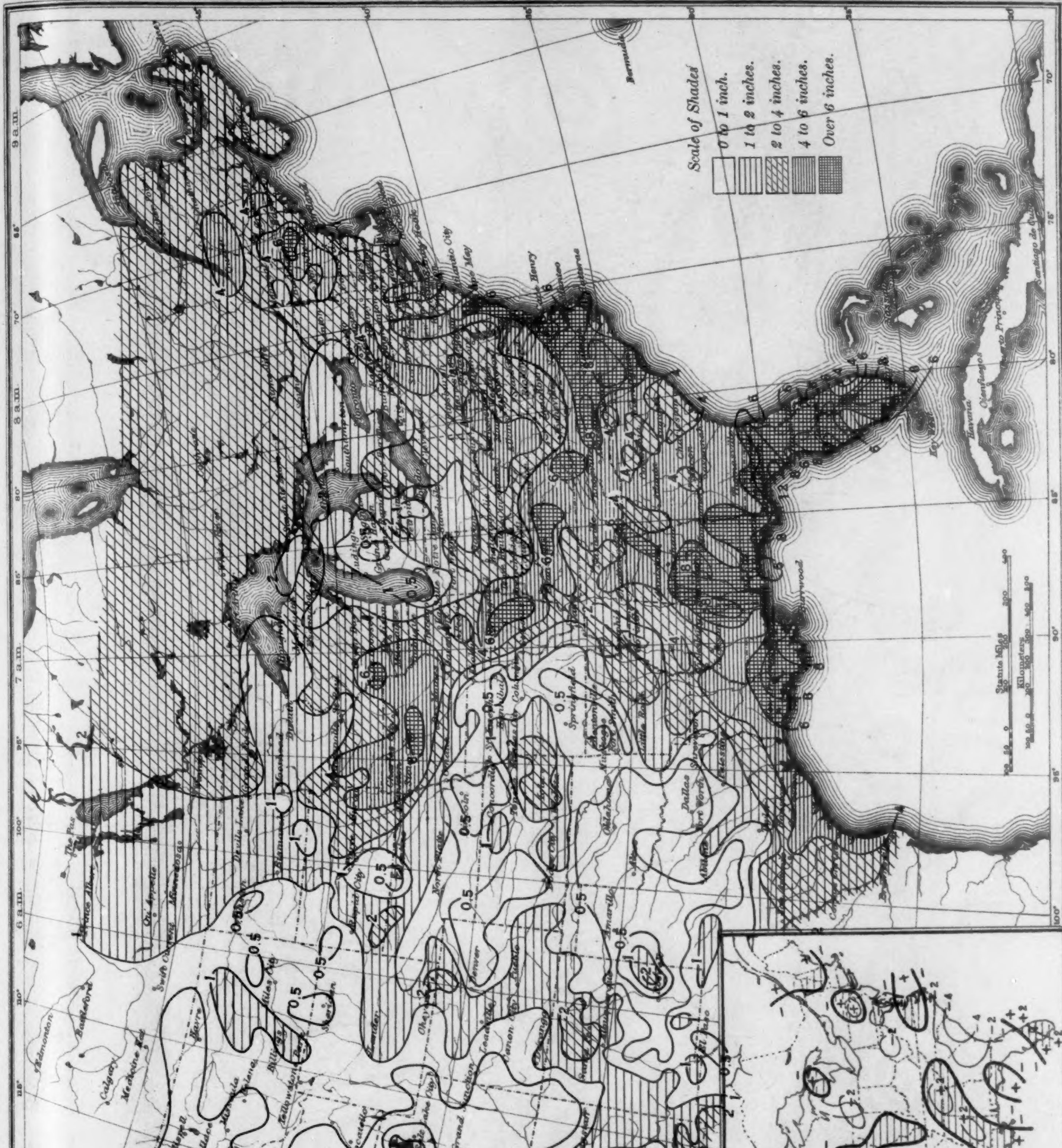


Chart VI. Isobars at Sea level and Isotherms at Surface; Prevailing Winds, July 1934

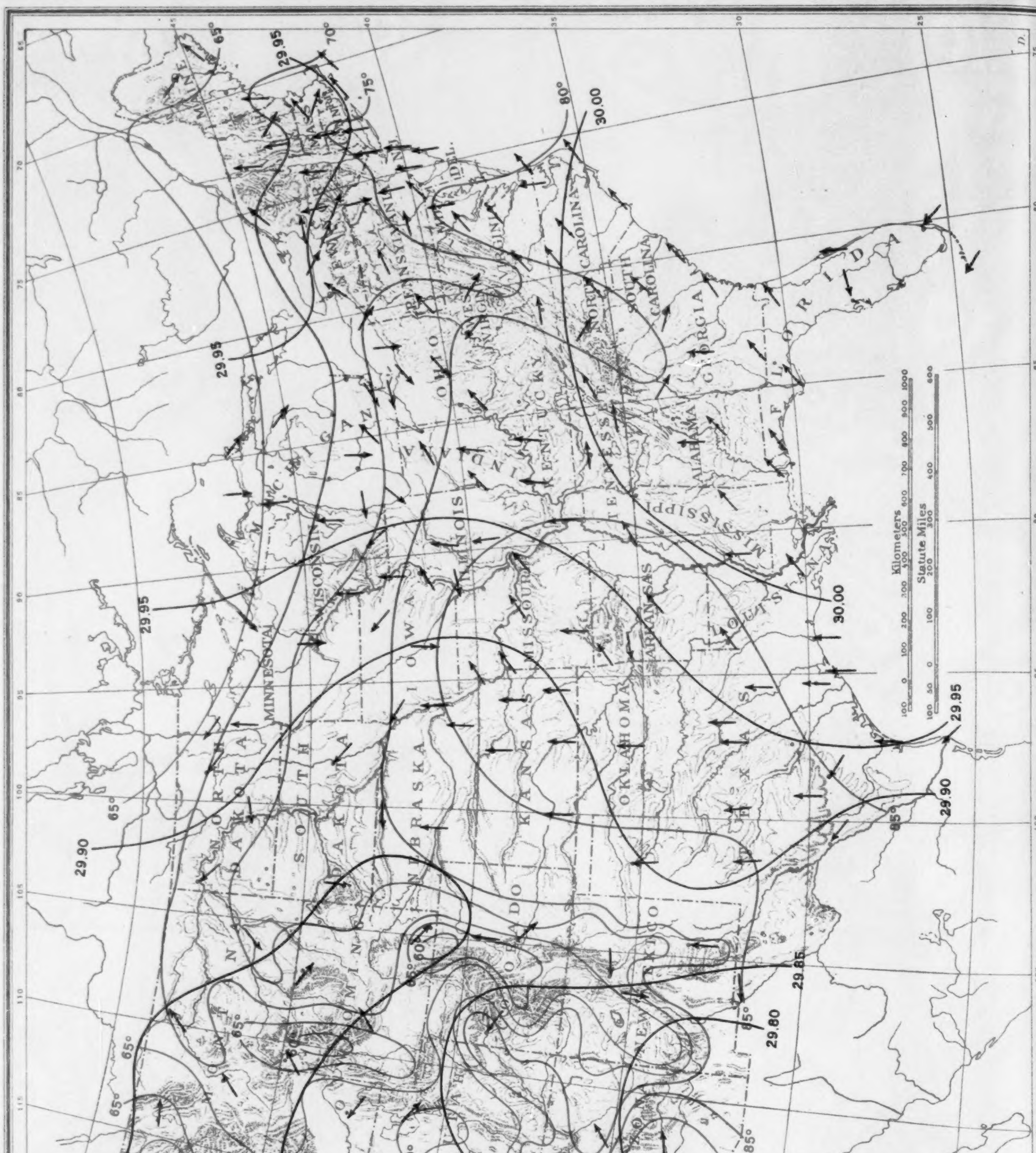


Chart VIII. Weather Map of North Atlantic Ocean, July 15, 1934
(Plotted from the Weather Bureau Northern Hemisphere Chart)

Chart VIII. Weather Map of North Atlantic Ocean, July 15, 1934
(Plotted from the Weather Bureau Northern Hemisphere Chart)

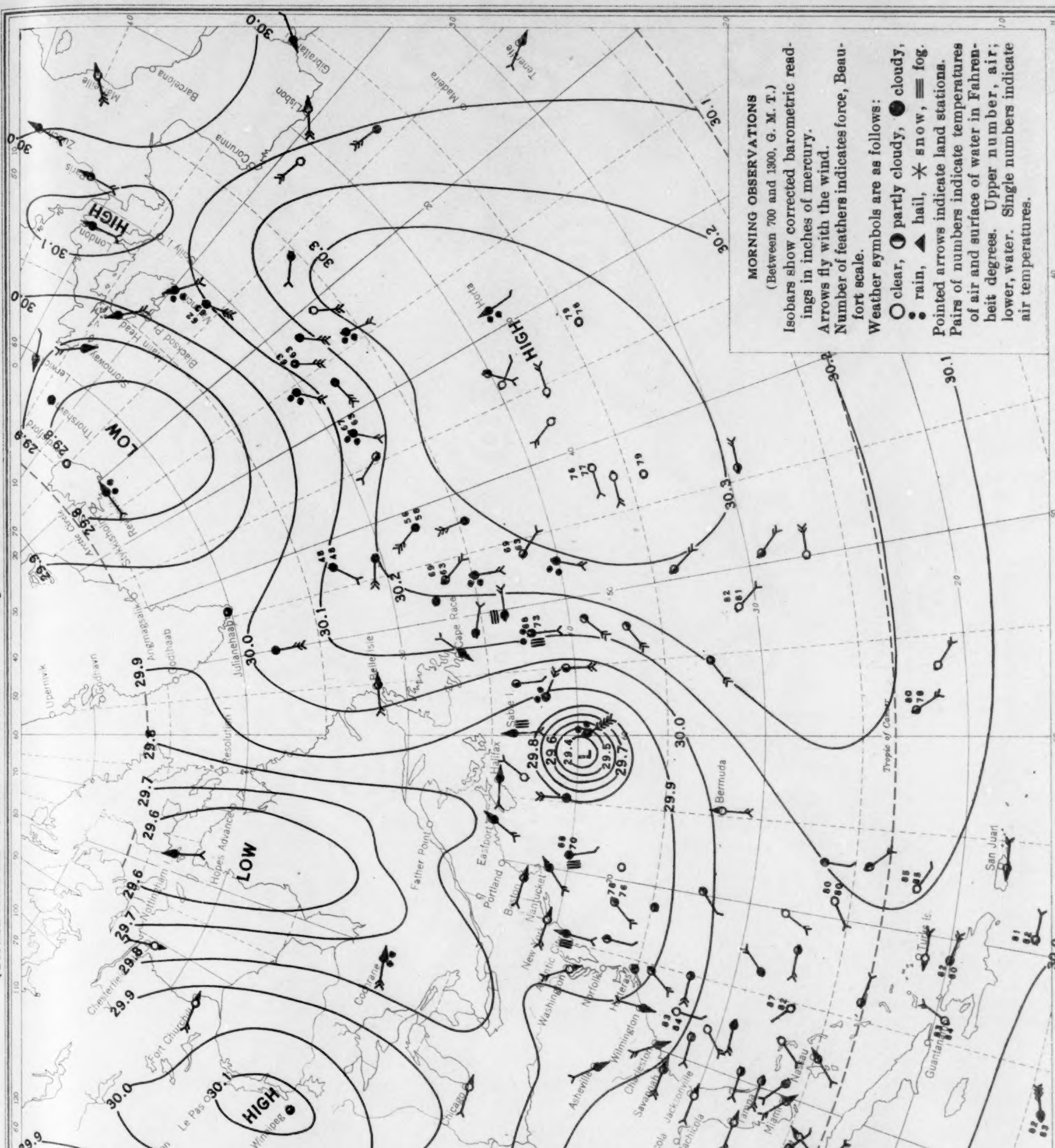


Chart IX. Weather Map of North Atlantic Ocean, July 25, 1934

(Plotted from the Weather Bureau Northern Hemisphere Chart)